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"MAKERS OF AMERICA"

ROBERT FULTON

HIS LIFE AND ITS RESULTS

BY

ROBERT H. THURSTON

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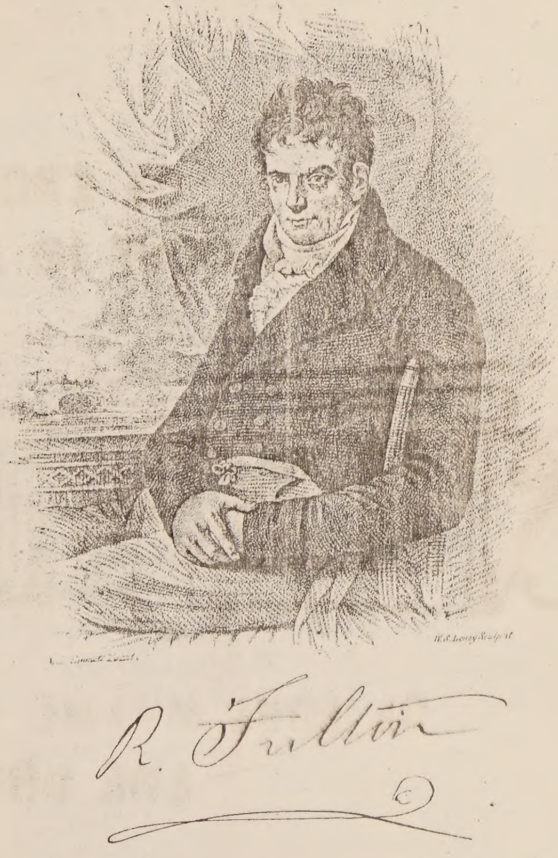
R. Fulton

CONTENTS.

ROBERT FULTON.

I.

OLD LEGENDS. — STEAM IN EARLIER TIMES. — JAMES WATT.

ROBERT FULTON has often, if not generally, been assumed to have been the inventor of the steamboat, as Watt is generally supposed to be the inventor of the steam-engine, which constitutes its motive apparatus. But this notion is quite incorrect. The invention of the steam-engine and that of the steamboat alike are the results of the inventive genius, not of any one man or of any dozen men, but have been the outcome of the inventive powers of the human race, exerted at intervals throughout the whole period of recorded history. An invention is usually, or is at least assumed to be, the product of the genius of some great mechanic, acting, as did the genii of old, by a single effort of the mysterious power. In this sense of the word, the steam-engine was never invented; rather it is the culmination of a long series of inventions of detail, and of improvements upon the earliest crude conceptions, and is the product of growth in a definite direction, and toward a now well-defined end. But while Fulton was not the inventor of the steamboat, and while James Watt was not the

inventor of the steam-engine, in a proper sense, it is the unquestionable fact that the latter was the first to secure a general introduction of the machine into practical use; and the former was the first to make the steamboat a commercial success, and to make its ultimate and permanent employment for marine transportation sure. As an inventor, Fulton accomplished far less than Watt; in fact, he did comparatively little in this realm of intellect. Watt invented many improvements of the steam-engine, and left it in vastly better form than when he found it, as it came from the hands of his predecessors, Newcomen and Calley. He gave the already well-shaped machine the separate condenser, the steam-jacket, the double-acting form, the rotative type, the expansive system, the governor, and the "engineer's stethoscope," — the indicator. Fulton did nothing to modify the engine, or to improve the steamboat even. He simply took the products of the genius of other mechanics, and set them at work, in combination, and then applied the already known steamboat, in his more satisfactorily proportioned form, to a variety of useful purposes, and with final success. It is this which constitutes Fulton's claim upon the gratitude and the remembrance of the nations. And it is quite enough.

The knowledge of the expansive power of steam was of earlier date than the Christian era; forms of steam-engine antedated Watt by two thousand years; the modern type of steam-engine was the invention of Newcomen rather than of Watt, and preceded that famous improver by nearly a century; the steamboat

was said to have been constructed by several inventors long before the world witnessed the birth of Fulton; other inventors had built and successfully operated steamboats with paddles, other boats with wheels, steam-vessels with screws, long before Fulton entered upon his great and glorious career. The simple fact is, therefore, as already indicated, that, like all really great and important inventions, these were the final fruition of minute germs of invention in earlier centuries, growing and gaining, century by century, throughout long periods of time. The famous inventor is usually he who in the end brings into full bearing the hitherto unknown and unnoticed invention, — he who at last makes it useful to mankind. This last was the mission of Fulton; and it is this which has entitled him to all the credit as an engineer, and all the fame, which has been indisputably his.

Before taking up our study of the life of Fulton, and of its magnificent results, as already exhibited after less than a century has passed, it will be both interesting and profitable to review the past, and learn, as well as history permits, the details of that growth which has led us finally to such wonderful fruition. In doing so, we will follow the thread of the narrative as it has already been given by the author in a more formal treatise.[1]

A rapid summary of the facts, and a study of their relations to our subject, beginning with earliest history, and following this development up to the time of Fulton, will enable us to more intelligently and

[1] History of the Growth of the Steam-Engine, by R. H. Thurston. New York. D. Appleton & Co. 1878.

satisfactorily weigh our debt to that great man, and measure the obligation of the world, and especially of his own country.

The knowledge of the latent power of steam probably antedates history; rude forms of apparatus for utilizing that force are described in the earliest of ancient works; yet the invention of a steam-engine, in the proper sense of that term, only took place within two centuries, and the steam-engine of the present time has been the outcome of a succession of inventions and improvements which are only now culminating in the production of an engine which science indicates to be that which must be regarded as the final form of that remarkable motor. The principles of its construction, and especially those of its operation, are now well understood, and all its faults and wastes of either heat-energy or mechanical power are known and measured, their causes ascertained, and, in a general way, their methods of remedy determined. We are now gradually overcoming the practical obstacles to the reduction of the machine to the best possible proportions, and its plan to the ideal form. The history of the steam-engine is exceedingly interesting, and to the philosopher especially so, as illustrating the fact that "great inventions are rarely the work of any one mind," but are "either an aggregation of minor inventions or the final step of a progression;" "not a creation, but a growth, — as truly so as that of the trees in the forest."[1]

[1] History of the Growth of the Steam-Engine, by R. H. Thurston. New York. D. Appleton & Co. (International Series.)

The first account of what has been termed the germ of the steam-engine appears in the works of Hero the Younger, who lived, as is supposed, in the second century before Christ, at Alexandria, in Egypt. In his "Pneumatica" he describes a multitude of devices, some of them very ingenious, but mainly mere toys, in which the heat-energy of fire, or of the sun, is applied for transformation into mechanical power through the intermediary of steam. He shows several forms of fountain, now known as the Hero fountain; contrivances for opening temple doors by steam; musical instruments, — at least, so called, — and other such unimportant trifles. Amongst this collection of curious illustrations of the non-utilitarian character of the Greek civilization, is found a real steam-engine, such as is illustrated by the accompanying engraving.[1]

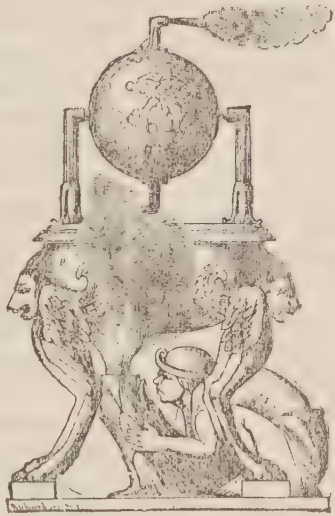

Fig. 1. — Hero's Steam-Engine.

The picture here given is a modern and highly

[1] Thurston's Manual of the Steam-Boiler, p. 2. New York. J. Wiley & Sons. 1890.

ornamented reproduction of Hero's machine, which is earliest shown in Stuart's "History of the Steam-Engine," 1829, and reproduced by the author in later publications. Curiously enough, this little machine, which has often been reproduced, unwittingly, by modern inventors, and actually used with a fair degree of satisfaction, illustrates a form of engine which is "theoretically," ideally perfect. Its operation under the theoretically best conditions, assuming it made with similar perfection and to be free from friction-wastes, would give highest possible efficiency and economy in the use of steam. But this would involve its operation at inapproachable velocities and the impracticable condition of being frictionless; nevertheless, it is perfectly possible to secure such favourable conditions in practice as will make a fairly economical machine, when placed in comparison with the forms of engine which modern invention has produced. Its action is simple and easily seen. Steam is made in the boiler which forms its base, and passes up through one or both of the hollow supporting columns or pipes, entering the axis of the whirling globe, filling it at a pressure determined by the rate at which steam is formed; and it is then expanded, finally issuing from the projecting arms or ajutages, and by its reaction turning the globe with considerable force and at high speed. Modern engines of this construction have been used quite successfully in driving factories and mills, and have been found to use no very extravagant amount of steam; but have finally been thrown out, on account, mainly,

of their cost for repairs; the whirling arms being usually rapidly cut away by their swift passage through the steam-laden atmosphere in which they necessarily work. Ideally, the machine is an "expansion-engine" of the most perfect type.

From the days of Hero, however, nothing more is heard of the use of steam in any apparatus, nor is any machine produced capable of doing work in that manner. All through the early and the middle ages the force of confined steam and other vapours is evidently known, but no attempt that may be regarded as at all serious was made to utilize its latent power. Little "æolipiles" — vessels in which steam was produced and from which it issued in a jet which was sometimes employed to cause an induced current of air with which to blow the fire — were the only steam-engines, until, about the sixteenth century, it seems to have been suspected by one or another of the wool-gathering philosophers and the plodding mechanics of those days that steam had a somewhat higher mission. At about the end of that century and the beginning of the seventeenth, we find records of various contrivances, in the application of steam to useful purposes, which indicate that at last the minds of men were awakening to the consideration of the problem of the centuries. These inventions, if it can be said, fairly, that they were inventions, were commonly directed to the application of the force of confined steam to the raising of water through considerable heights, as in the draining of mines, or in furnishing a house-supply. Da Porta,

in 1601, De Caus in 1605 to 1615, and Branca, 1629, were among those who began to suggest, rather than to practise, the application of steam to useful work. The first two pictured contrivances for raising water, which were, however, but distant imitations of the notions of Hero; while the last-named gave drawings, with some elaboration, of machines, by the action of steam-jets, usually impinging against vanes, driving mills and metallurgical machinery.

At about the latter time, the second Marquis of Worcester began his now famous career of invention, and probably as early as 1630 had devised what is known as his "engine" or his "fire-engine;" a machine, however, which was really but the Hero fountain on an enlarged and somewhat more practically available scale, and in better form. He did apply it to its purpose of raising water, though; and this constitutes for him a legitimate and sufficient claim for remembrance and honour. He was the first to use steam — so far as is positively known — for industrial ends. It is known that he was engaged in erecting an engine at least as early as 1648, but his patents were only issued in 1663. It seems very certain that the marquis built two or more of these "fire-engines;" but their exact form is unknown, and it is only certain that he profited nothing by his ingenuity and enterprise. He finally died unsuccessful and in comparative poverty. His widow was as unhappy and unfortunate as her husband, and died in 1681 without having gained a foothold for her spouse's invention.

The death of this truly great man, inventor and statesman as he was, in the highest sense, did not, however, put an end to the progress which he had initiated. His friend and successor in this work, Sir Samuel Morland, made himself thoroughly familiar with the subject, secured opportunities to construct a number of such engines, and became so well informed as to their capabilities that he published an account of the apparatus, in which paper he introduced tables of the number and sizes of the working cylinders required to raise given quantities of water to specified heights in stated times; thus, for the first time, constructing the now usual specifications for use in determining the requirements of purchasers. Yet neither the machines of Worcester nor those of Morland became generally used. These men were in advance of their time; and it was only when, some years later, Captain Savery, — a man of talent both as an engineer and a man of business, whose character united all the elements of success in practical operations, — took up the task that it became in any degree a commercial success. Very little is known in detail of the experiments or of the constructions of the Marquis of Worcester; and that absorbing romance by George Macdonald, "St. George and St. Michael," may perhaps be taken as quite as authoritative as any biography, so far as such minor details are concerned; but the work of Savery, nearly a half-century later, came within the range of modern history, and is well understood.

When Savery took up the new problem, at the

opening of the eighteenth century, the mines of Great Britain had become, in many instances, so deep that the labour of freeing them from water was an enormously difficult and expensive task with the means and apparatus at the disposition of the mine-owners. They had rude forms of pump worked by horse-power almost exclusively; and in the older and more extensive mines, hundreds of horses were sometimes kept at work, and the profits of mining were becoming daily less and less, and seemed likely to be soon extinguished by this great tax on production. Worcester and his contemporaries had seen this threatening outlook, and were apprehensive that Britain might soon lose that supremacy, industrially, which she had, in consequence of her success in mining, up to that time so firmly held. They had, in many cases, looked to steam or some as yet undiscovered motor to do this work more cheaply than horse-power; but even Worcester and Morland failed to make practically useful application of the new "fire-engine." Savery, familiar with the business of mining, a mechanic by experience and practice as well as by nature, not only saw the opportunity, but saw also a way to secure a prize. He made a workmanlike reproduction of the Worcester machine, giving it a form capable of immediate and effective application to the intended purpose. This is his device, as built by him for mines, and as described by him to the Royal Society, then already (1698) formed and in operation, and to the public through his little book, "The Miner's Friend; or, A Description of an Engine to raise Water by

Fire described, and the Manner of fixing it in Mines, with an Account of the several Uses it is applicable to, and an Answer to the Objections against it. Printed in London in 1702 for S. Crouch." It was

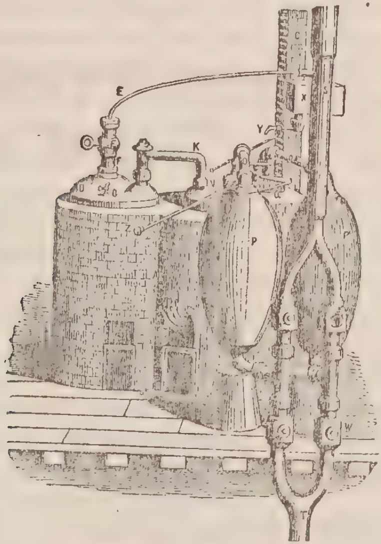

Fig. 2. — Savery's Engine, A. D. 1702.

distributed among the proprietors and managers of mines, who were then finding the flow of water at depths so great as, in some cases, to bar further progress.

The engraving of the engine was reproduced, with the description, in Harris's "Lexicon Technicum,"

1704; in Switzer's "Hydrostatics," 1729; and in Desagulier's "Experimental Philosophy," 1744.[1]

In Figure 2, *L L* is the boiler in which steam is raised, and through the pipes *O O* it is alternately let into the vessels *P P*. Suppose it to pass into the left-hand vessel first. The valve *M* being closed, and *r* being opened, the water contained in *P* is driven out and up the pipe *S* to the desired height, where it is discharged. The valve *r* is then closed, and the valve in the pipe *O;* the valve *M* is next opened, and condensing water is turned upon the exterior of *P* by the cock *Y*, leading water from the cistern *X*. As the steam contained in *P* is condensed, forming a vacuum there, a fresh charge of water is driven by atmospheric pressure up the pipe *T*. Meantime, steam from the boiler has been let into the right-hand vessel *Pp*, the cock *W* having been first closed, and *R* opened. The charge of water is driven out through the lower pipe and the cock *R*, and up the pipe *S* as before, while the other vessel is refilling preparatory to acting in its turn. The two vessels are thus alternately charged and discharged, as long as is necessary.

Savery's method of supplying his boiler with water was as follows: —

The small boiler, *D*, is filled with water from any convenient source, as from the stand-pipe, *S*. A fire is then built under it, and when the pressure of steam in *D* becomes greater than in the main boiler, *L*, a communication is opened between their lower ends,

[1] Our illustration is from Thurston's "History of the Steam-Engine," p. 37. New York. D. Appleton & Co.

and the water passes, under pressure, from the smaller to the larger boiler, which is thus "fed" without interrupting the work. *G* and *N* are *gauge-cocks*, by which the height of water in the boilers is determined; they were first adopted by Savery.

"Here we find, therefore, the first really practicable and commercially valuable steam-engine. Thomas Savery is entitled to the credit of having been the first to introduce a machine in which the power of heat, acting through the medium of steam, was rendered generally useful. It will be noticed that Savery, like the Marquis of Worcester, used a boiler separate from the water-reservoir. He added to the 'water-commanding engine' of the marquis the system of *surface-condensation*, by which he was enabled to charge his vessels when it became necessary to refill them; and added, also, the secondary boiler, which enabled him to supply the working-boiler with water without interrupting its action. The machine was thus made capable of working uninterruptedly for a period of time only limited by its own decay. Savery never fitted his boilers with safety-valves, although it was done later by others; and in deep mines he was compelled to make use of higher pressures than his rudely-constructed boilers could safely bear." [1]

In this case, we find an illustration of a very common fact in the history of inventions: The originator of this machine was probably, perhaps undoubtedly,

[1] Thurston's History of the Steam-Engine, p. 38. See, also, Thurston's Manual of Steam-Boilers. New York. J. Wiley & Sons.

the second Marquis of Worcester; but the practical constructor, and the finally successful inventor, was Savery, the man who combined inventive with constructive power and business ability in that way which is almost always essential to complete success. Savery was more an "exploiter" of this invention than its author. Yet he did introduce some excellent modifications of details, and the various practically useful minutiæ which so often are the prime requisite to commercially satisfactory work. A glance at the drawings of the machine, however, and a comparison with the modern steam-engine will show that this was not only not a steam-engine in the usual sense, a train of mechanism, but that it belongs to an entirely different class of apparatus. A real steam-engine was only invented after experience with the Savery apparatus had shown it to be a wasteful, dangerous, and comparatively rude contrivance for the application of steam to the work of raising water. It was wasteful in consequence of the fact that it applied the pressure of the steam at the surface of the cold water to be raised, and was thus certain to condense much more than it could usefully employ; it was dangerous in consequence of the fact that it must necessarily use pressures exceeding those of head of water to be encountered, and higher than the mechanics of that time could make their boilers and "forcing-vessels" capable of safely withstanding. More than one explosion actually occurred.

It is here that we meet with perhaps the greatest of all the inventors of the steam-engine, — the man who

for the first time produced a steam-engine of the modern type; a train of mechanism, in which a steam-engine was constructed and applied to another machine for the purpose of acting as its "prime mover," — an engine operating a pump. This greatest of the whole line of inventors, considered from the point of view of the historian of the engine and the student of its philosophy, was, not Watt, but Newcomen, or perhaps more precisely, two mechanics, Thomas Newcomen and John Calley or Cawley, who patented the new engine, 1705, soon after Savery's machine had come to be fairly well known. Savery also controlled some of the patents incorporated in the new arrangement, and took an interest with its inventors, and shared their profits.

Newcomen's engine, by employing steam of low, hardly more than atmospheric, pressure, evaded the dangers inherent in that of Savery, and by applying the steam to move a piston in a cylinder apart from the pump, secured comparatively economical performance. It promptly displaced the older and ruder contrivance, and came into use all over Europe, as constructed later by Smeaton and other great engineers of the day. As finally given form by these able men, it is seen in the next engraving, which shows the machine as built by Smeaton in 1774, for the Long Benton colliery.[1] The boiler is not shown in the sketch. Figure 3 illustrates its characteristic features.[2]

[1] History of the Steam-Engine, p. 65.

[2] A fac-simile of a sketch in Galloway's "On the Steam-Engine," etc.

The steam is led to the engine through the pipe, *C*, and is regulated by turning the cock in the receiver, *D*, which connects with the steam-cylinder by the pipe, *E*, which latter pipe rises a little way above the

Fig. 3.—Smeaton's Newcomen Engine.

bottom of the cylinder, *F*, in order that it may drain off the injection-water into the steam-pipe and receiver.

The steam-cylinder, about 10 ft. (3 m.) in length, is fitted with a carefully-made piston, *G*, having

a flanch rising 4 or 5 inches (.1 to 1.25 m.) and extending completely around its circumference, and nearly in contact with the interior surface of the cylinder. Between this flanch and the cylinder is driven a "packing" of oakum, which is held in place by weights; this prevents the leakage of air, water, or steam past the piston, as it rises and falls in the cylinder at each stroke of the engine. The chain and piston-rod connect the piston to the beam *I I*. The arch-heads at each end of the beam keep the chains of the piston-rod and the pump-rods perpendicular and in line.

A "jack-head" pump, *K*, is driven by a small beam deriving its motion from the plug-rod at *g*, raises the water required for condensing the steam, and keeps the cistern, *O*, supplied. This "jack-head" cistern is sufficiently elevated to give the water entering the cylinder the velocity requisite to secure prompt condensation. A waste-pipe carries away any surplus water. The injection-water is led from the cistern by the pipe, *P P*, which is two or three inches in diameter; and the flow of water is regulated by the injection-cock, *r*. The cap at the end, *d*, is pierced with several holes, and the stream thus divided rises in jets when admitted, and, striking the lower side of the piston, the spray thus produced very rapidly condenses the steam, and produces a vacuum beneath the piston. The valve, *e*, on the upper end of the injection-pipe, is a check-valve to prevent leakage into the engine when the latter is not in operation. The little pipe, *f*, supplies water to the

upper side of the piston, and, keeping it flooded, prevents the entrance of air when the packing is not perfectly tight.

The "working-plug," or plug-rod, *Q*, is a piece of timber slit vertically, and carrying pins which engage the handles of the valves, opening and closing them at the proper times. The steam-cock, or regulator, has a handle, *h*, by which it is moved. The iron rod, *i i*, or spanner, gives motion to the handle, *h*.

The vibrating lever, *k l*, called the *Y* or the "tumbling bob," moves on the pins, *m n*, and is worked by the levers, *o p*, which in turn are moved by the plug-tree. When *o* is depressed, the loaded end, *k*, is given the position seen in the sketch, and the leg, *l* of the *Y* strikes the spanner, *i i*, and, opening the steam-valve, the piston at once rises as steam enters the cylinder, until another pin on the plug-rod raises the piece, *P*, and closes the regulator again. The lever, *q r*, connects with the injection-cock, and is moved, when, as the piston rises, the end, *q*, is struck by a pin on the plug-rod, and the cock is opened and a vacuum produced. The cock is closed on the descent of the plug-tree with the piston. An eduction-pipe, *R*, fitted with a clock, conveys away the water in the cylinder at the end of each down-stroke; the water thus removed is collected in the hot-well, *S*, and is used as feed-water for the boiler, to which it is conveyed by the pipe *T*. At each down-stroke, while the water passes out through *R*, the air which may have collected in the cylinder is driven out through the "snifting-valve," *s*. The steam-cylinder

is supported on strong beams, *t t*; it has around its upper edge a guard, *v*, of lead, which prevents the overflow of the water on the top of the piston. The excess of this water flows away to the hot-well through the pipe *W*.

Catch-pins, *x*, are provided, to prevent the beam descending too far should the engine make too long a stroke; two wooden springs, *y y*, receive the blow. The great beam is carried on sectors, *z z*, to diminish losses by friction.

Comparing this machine with that of Savery, it is seen that the dangers of the form previously in use are here evaded, while economy is enormously promoted by the change. As it is here practicable to employ steam of but slightly more than atmospheric pressure, no danger of explosions consequent upon high pressure in regular working is encountered. By the separation of the pump from the working cylinder, and the application of the steam to a piston, instead of to a surface of cold water, the immense condensation to which it was subjected in the Savery engine is largely reduced. Thus both safety and economy are gained. It is therefore not at all surprising that this new invention should have come immediately into general use, and should have promptly become the standard form of the steam-engine for its time. It was built not only f[illegible]ll the principal mines of Great Britain, but also fo[illegible] of the continent of Europe; and long after the death of its inventors the genius of that greatest of engineers of his time, Smeaton, continued to sustain it

and to keep it in use, even as a rival of the most famous of this whole line of inventions, — that of James Watt, who now comes upon the scene. Smeaton himself built a large number of these engines; and at the time of his death, about the end of the eighteenth century, there were not less than a hundred Newcomen engines in Great Britain, and many elsewhere in Europe.

Notwithstanding the great advantage possessed by this engine when compared with that of Savery, it was, compared with our modern standards, a very wasteful machine. Its wastes occurred through the same causes precisely as those operating in the case of its predecessor, and though in less degree, still to a very serious extent. In the operation of the pump-end it had become efficient; but the steam-cylinder was both a power-producing mechanism and a condenser of steam, — for the condensation of the one working-charge was produced by the introduction of water, cooling the cylinder itself, as well as the steam which it contained. This cooling compelled a subsequent heating by the next charge of steam, and consequent condensation and waste proportional to the quantity thus demanded, — a very large fraction of all entering the engine. Its "duty" was about six millions of pounds of water raised one foot high by a bushel of coals, — the usual measure of efficiency of engines in those days. This was but about a quarter of that obtained a little later by Watt, and but a tenth of that secured ultimately by his best engines. It was about five per cent of what is

to-day considered the maximum duty of the modern engine of the best type.

It is to James Watt that we owe the latest and crowning improvements of the steam-engine, as we know it to-day. A half-century after Newcomen he found among the collections of the then and still celebrated University of Glasgow — always famous for its success in the promotion of the physical sciences — a model of the still-used engine of that earlier and no less deserving inventor. He was, in the course of his duty as the instrument-maker to the college, called upon to put this little machine in repair; and having done so, he became interested in studying its working. He was surprised to find that its steam-cylinder absorbed, each stroke, four times as much steam as its measurement would indicate to be possible, three fourths of that entering being evidently condensed, and only one fourth doing work. This waste of seventy-five per cent of all the steam supplied, and of a similar proportion of the fuel used in generating it, and of the money demanded for the operation of the engine, seemed so extraordinary that the active mind of the great inventor was at once applied to remedy so singular and immense a loss.

Watt saw at once that the remedy must consist in some way of reducing this liquefaction of the steam by, as he said, "keeping the steam cylinder as hot as the steam entering it." This he did by first effecting the condensation of the steam in a separate condenser, instead of in the cylinder; then surrounding the cylinder itself by a "steam-jacket," in which he

kept steam at boiler-pressure, thus preventing any cooling off of the engine during the period of its operation. In his patent of 1769, he says, —

"My method of lessening the consumption of steam, and consequently fuel, in fire-engines, consists in the following principles: —

"1st. That the vessel in which the powers of steam are to be employed to work the engine — which is called 'the cylinder' in common fire-engines, and which I call 'the steam-vessel' — must, during the whole time that the engine is at work, be kept as hot as the steam which enters it: first, by inclosing it in a case of wood, or any other materials that transmit heat slowly; secondly, by surrounding it with steam or other heated bodies; and thirdly, by suffering neither water nor other substances colder than the steam to enter or touch it during that time.

"2dly. In engines that are to be worked, wholly or partially, by condensation of steam, the steam is to be condensed in vessels distinct from the steam-vessel or cylinder, though occasionally communicating with them. These vessels I call *condensers*; and while the engines are working, these condensers ought at least to be kept as cold as the air in the neighbourhood of the engines, by application of water or other cold bodies.

"3dly. Whatever air or other elastic vapour is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam-vessels or condensers by means of pumps, wrought by the engines themselves, or otherwise.

"4thly. I intend in many cases to employ the expansive force of steam to press on the pistons, or whatever may be used instead of them, in the same manner as the pressure of the atmosphere is now employed in common fire-engines. In cases where cold water cannot be had in plenty, the engines may be wrought by this force of steam only, by discharging the steam into the open air after it has done its office."

Thus he converted the "atmospheric engine" of Newcomen into the steam-engine of James Watt. His separate condenser, with its air-pump; his covered cylinder, permitting the contact of hot steam instead of cold air with the top of the piston; his steam-jacket, and his generally improved construction, at once gave him a machine which was capable of doing four times as much work, on the same expenditure of money for fuel, as the older engine. A capitalist, Matthew Boulton, joined with Watt in the formation of a company for the manufacture of the new engine; and the firm of Boulton and Watt became promptly known all over the civilized world, and is likely to be remembered as long as the steam-engine endures. This partnership was formed in 1769, and from that time on, for years, Watt found employment for all his genius in the improvement and adaptation of the engine for its countless purposes.

In 1781 Watt invented the now familiar "double-acting" engine, applied to turning a shaft, and to the driving of machinery in factories and mills. His patent included, —

(1) The expansion of steam, and six methods of

applying the principle and of equalizing the expansive power.

(2) The double-acting steam-engine, in which the steam acts on each side the piston alternately, the opposite side being in communication with the condenser.

(3) The double or coupled steam-engine, — two engines capable of working together, or independently, as may be desired.

(4) The use of a rack on the piston-rod, working into a sector on the end of the beam, thus securing a perfect rectilinear motion of the rod.

(5) A rotary engine, or "steam-wheel."

The efficiency to be secured by the expansion of steam had long been known to Watt, and he had conceived the idea of economizing some of that power, the waste of which was so plainly indicated by the violent rushing of the exhaust steam into the condenser, as early as 1769. This was described in a letter to Dr. Small, of Birmingham, in May of that year; and the earlier Soho engines were, as Watt said, made with cylinders "double the size wanted, and cut off the steam at half-stroke." But though "this was a great saving of steam, so long as the valves remained as at first," the builders were so constantly annoyed by alterations of the valves by proprietors and their engineers that they finally gave up that method of working, hoping ultimately to be able to resume it when workmen of greater intelligence and reliability could be found. The patent was issued July 17, 1782.[1]

[1] History of the Steam-Engine, p. 105.

During the following two years or more, Watt was engaged in bringing out and perfecting a number of the minor inventions, the accessories of the engine, — as the governor, the counter, the numerous little details of construction and of valve mechanism; finally, in 1784, he patented a group which included these, and the steam-hammer, and the locomotive. The steam-engine had now taken its distinctively modern form, and may be said to have been substantially completed; and Watt's work was mainly done. The form of the engine as now built by the firm is seen in the next engraving, which is a reproduction of his own drawings made at that date.

In Figure 4, *C* is the steam-cylinder, *P* the piston, connected to the beam by the link, *g*, and guided by the parallel motion *g d c*. At the opposite end of the beam a connecting-rod, *O*, connects with the crank and fly-wheel shaft. *R* is the rod of the air-pump, by means of which the condenser is kept from being flooded by the water used for condensation, which water-supply is regulated by an "injection-handle," *E*. A pump-rod, *N*, leads down from the beam to the cold-water pump, by which water is raised from the well or other source to supply the needed injection-water. The air-pump rod also serves as a "plug rod," to work the valves, the pins at *n* and *R* striking the lever, *m*, at either end of the stroke. When the piston reaches the top of the cylinder, the lever, *m*, is raised, opening the steam-valve, *B*, at the top, and the exhaust-valve, *E*, at the bottom, and at the same time closing the exhaust at the top and the steam at the

bottom. When the entrance of steam at the top and the removal of steam-pressure below the piston has driven the piston to the bottom, the pin, *R*, strikes the lever, *m*, opening the steam and closing the exhaust valve at the bottom, and similarly reversing the position of the valves at the top. The position of the valves is changed in this manner with every reversal of the motion of the piston.

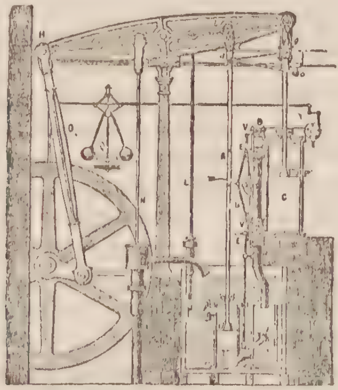

Fig. 4.— Boulton and Watt's Double-Acting Engine, 1784.

The earliest engines of the kind, and of any considerable size, were those set up in the Albion Mills, near Blackfriars' Bridge, London, in 1786, and destroyed when the mills burned in 1791. These were a pair of engines, of fifty horse-power each, and geared to drive twenty pairs of stones, making fine flour and meal. Previous to the erection of this mill the power in all such establishments had always been derived from wind-mills and water-wheels.

At the time of Watt's death, 1819, the steam-engine had thus been brought into its now familiar and standard form, and had been prepared, by its various modifications of detail, to do its work in all now usual directions. The engine itself was substantially complete in form. It had been given such construction as would permit the expansive use of the motor-fluid, and thus the attainment of high economy; the wastes had been reduced to a comparatively small amount; and the applications of the machine to the raising of water, the driving of mills, the impulsion of railway-carriages, and of vessels, had been proposed and, tentatively, begun in all directions. It was now possible to begin a new line of engineering development, — that of application to all the purposes of modern life. It is this which has been the distinctive industrial characteristic of the nineteenth century. As we have seen, Watt may not claim the honour of being the inventor of the steam-engine; but he is unquestionably entitled to that of having been the most fruitful of inventors, and the man to whom most credit is due for having applied the machine to its myriad purposes, making it the universal servant and friend of mankind. It is this which entitles him to the famous eulogy in his epitaph, as the inventor who, "directing the force of an original genius, early exercised in philosophic research, to the improvement of the steam-engine, enlarged the resources of his country, increased the power of man, and rose to an illustrious place among the most eminent followers of science, and the real benefactors of the world."

II.

EARLY EXPERIMENTS IN STEAM-NAVIGATION.

EVEN before the time of Watt, the possibility of the application of the motive power of steam to the impulsion of vessels had been, by many inventors, believed to be unquestionable; and a number of attempts to so apply it had been made. But so rude were the machines of those earlier times, and so impossible was it to secure good construction of even the simplest mechanism, that no permanent success had been achieved by any one of these enthusiastic schemers. As early as the thirteenth century, Roger Bacon, one of the founders of the modern system of experimental philosophy, wrote, "I will now mention some wonderful works of art and nature in which there is nothing of magic, and which magic could not perform. Instruments may be made by which the largest ships, with only one man guiding them, will be carried with greater velocity, than if they were full of sailors." [1]

As soon as the steam-engine took practically available form, it was proposed to use it for this purpose, and Papin, in 1690, suggested the use of his piston engine in this direction. He actually constructed a

[1] History of the Steam-Engine, p. 224.

steamboat, in 1707, on the river Fulda, at Cassell, using his pumping-engine to raise water; which water in turn was applied to a water-wheel, and drove thus a set of paddle-wheels on the same shaft. The contrivance, crude as it was, was found capable of doing its work, and the boat might have been the pioneer in a commercially successful use of steam for navigation, had it not been promptly destroyed by the ignorant and superstitious boatmen of the neighbourhood, who thought it the work of the Evil One. Papin, disappointed and discouraged, fled to England, and there, becoming well known as a fellow of the Royal Society, resided until his death, in poverty, about 1712.

A little later, 1736, Jonathan Hulls, of whom nothing seems to be otherwise known, patented a steamboat, of which he gave a very imperfect description, but which he is said to have constructed and successfully tried, and an account of which he published in pamphlet form in 1737. Its frontispiece is a rude illustration of the proposed boat, and also gives some slight idea of the nature of the details of his machinery, which seems to have included some modification of the Newcomen engine. This has been reproduced in fac-simile in later works.[1]

Bernouilli, in 1752, proposed the use of a screw as a propelling instrument. L'Abbé Gauthier, according to Figuier,[2] about the same time suggested the [illegible] of the steam-engine in navigation, driving paddle-wheels, and also that it should be used for operating the pumps, for raising the anchor, and ventilating the ves-

[1] History of the Steam-Engine, p. 226.

[2] Les Merveilles de la Science.

sel, and that the fire should, at the same time, be used for cooking. He designed to use the Newcomen engine.

Many other inventors were now studying the problem in different parts of the civilized world. Among these, none were as ingenious or as persistent or as successful as those of the then British colonies, later the United States of America. Among these was a group of New York and Pennsylvania mechanics, who, seemingly each more or less familiar with the work of the others, struggled on persistently, and finally successfully. A nucleus consisting of one of these men and his friends and coadjutors, became, ere long, the germ of the great movement which in the early part of the nineteenth century resulted in the final application of the powers of steam to the propulsion of steam-vessels, — first on the rivers of the United States and the harbours of Great Britain, then on all the oceans. The originator of this sudden movement in the United States seems to have been a man unknown to fame, and one of whom few records are preserved. Our own information, hitherto unpublished, comes from an indistinctly traced source; but its facts have been fairly well verified by independent historical investigation.

William Henry was born in Chester County, Penn., in the year 1729. His father, John Henry, with his parents, and two brothers, — Robert and James, — emigrated to this country from the north of Ireland in or about the year 1719 or 1720.[1] The father of

[1] Robert and James Henry married sisters, named Mary Ann and Sarah Davis, who resided in Chester County. Rob-

James, Robert, and John was a native of Scotland, but for a short time previous to his coming to this country had resided in one of the northern counties of Ireland. Upon the arrival of the family in Pennsylvania they settled in Chester County, where, as before stated, the subject of our sketch was born. At an early age he became a resident of Lancaster, Penn., where he learned the business of gunsmith. After serving his apprenticeship he began business on his own account, and in a few years became the principal gunsmith in the province. During the Indian wars which desolated Pennsylvania from 1755 to 1760, he was appointed principal armourer of the troops then called into service, which position procured for him the honour of having his name given to a fort in Berks County constructed by the Proprietary Government, on the then frontier settlements, under the immediate supervision of Benjamin Franklin, to whom Mr. Henry was well known, and who appreciated his services in that eventful period.

In the year 1760 Mr. Henry went to England on business connected with his vocation, and there he remained for some time. Having a mechanical turn of mind, the inventions and the applications of steam by Watt being then much discussed, the idea of its application to the propelling of boats, vehicles, etc., so engrossed his mind that on his return to his

ert subsequently removed to Virginia; and from the circumstances of the two brothers having married the sisters, Mary Ann and Sarah Davis, it has been ascertained that the celebrated Patrick Henry was a descendant of this Robert Henry.

home in Lancaster he began the construction of a machine, the motive power of which was steam. In 1763 Mr. Henry completed the machine, which was attached to a boat with paddles, and with it he experimented on the Canastoga River, near Lancaster; but the boat was by some accident sunk.[1]

This was the first attempt that ever had been made to apply steam to the propelling of boats. Notwithstanding the ill luck that attended the first attempt in an undertaking of the practicability of which he had not the least doubt, he constructed a second model, with improvements on the first; and among the records of the Pennsylvania Philosophical Society is to be found a design, presented by him in 1782, of a machine, the motive power of which was steam. An intelligent German traveller named Shoepff, who travelled through the United States in 1783–1784, whilst staying for a time at Lancaster, became acquainted with Mr. Henry. He says: "I was shown a machine by Mr. Henry, intended for the propelling of boats, etc., 'but,' said Mr. Henry, 'I am doubtful whether such a machine would find favour with the public, as every one considers it impracticable to make a boat move against wind and tide;' but that such a boat *will* come into use, and navigate on the waters of the Ohio and Mississippi he had not the least doubt, though the time had not yet arrived of its being appreciated and applied." A sketch of the machine, with the boilers, etc., made by Mr.

[1] See Bowen's "Sketches," collected in Pennsylvania.

Henry in 1779, is said to be still in the possession of his heirs.

John Fitch (for whom his biographer claimed the honour of the invention of the application of steam to the propulsion of boats) was a frequent visitor at Mr. Henry's house, and according to the belief of his friends obtained from him the idea of the steamboat. Fulton, then a young lad, also visited Mr. Henry's to examine the paintings of Benjamin West; and the germ that subsequently ripened into the construction of the "Folly" was possibly due to those visits. Mr. Henry's decease occurred on the 15th of December, 1786.

William Henry, though unsuccessful with the experiments with his first boat on the Canastoga River, thus very probably originated the idea of the steamboat at least five years before Fulton was born. The following extract[1] may throw some light on the subject :—

"Dec. 2d, 1785. At a special meeting of the Philosophical Society, John Fitch was personally presented to the members. Desirous of having the opinion of men of weight at that period, he consulted several, among whom was Mr. Henry, of Lancaster, 'who informed me,' says Fitch, 'that he was the first person who had thought of applying steam to vessels; that he had conversed with Mr. Paine, author of "Common Sense," and some time after, Mr. Henry, thinking more seriously of the matter,

[1] Inventor's Guide, by J. G. Moore.

was of the opinion that it might be perfected, and accordingly made some drafts, which he laid before the Philosophical Society.' "

Fitch evidently made the first successful experiment in the propelling of boats by steam; but William Henry has probably the honour of originating the idea, and building the first steamboat ever built in the United States. Fitch improved on Mr. Henry's model, and Fulton improved on both.

Thus a group of alert, intelligent, enterprising men, in this little town, far back among the then wilds of Pennsylvania, were all interested in the solution of a new problem. Of all these men, two — Fitch and Fulton — have since been known as the most successful among the inventors who took part in the introduction of steam navigation in the United States. At the same time the great mechanics of the country were preparing themselves to take their part in the work, and in 1775 the first steam-cylinder for a stationary steam-engine was cast in New York City, by the firm of Sharpe & Curtenius;[1] while the application of the steam-engine to navigation was attempted in a rude way, since often tried and as often failing, by James Rumsey.

Rumsey's experiments began in 1774, and in 1786 he succeeded in driving a boat at the rate of four miles an hour against the current of the Potomac at Shepherdstown, Va., in presence of General Washington. His method of propulsion has often been reinvented since, and its adoption urged with that

[1] Rivington's Gazette, Feb. 16, 1775

enthusiasm and persistence which is a peculiar characteristic of inventors.

Rumsey employed his engine to drive a great pump, which forced a stream of water aft, thus propelling the boat forward, as proposed earlier by Bernouilli.

Rumsey died of apoplexy while explaining some of his schemes before a London society a short time later, December 23, 1793, at the age of fifty years. A boat then in process of construction from his plans was afterward tried on the Thames, in 1793, and steamed at the rate of four miles an hour. The State of Kentucky in 1839 presented his son with a gold medal, commemorative of his father's services "in giving to the world the benefit of the steamboat."[1] The first President of the United States certified his familiarity with this device, thus: —

> I have seen the model of Mr. Rumsey's boat, constructed to work against the stream; examined the powers upon which it acts; been eye-witness to an actual experiment in running waters of some rapidity; and give it as my opinion (although I had little faith before) that he has discovered the art of working boats by mechanism and small manual assistance against rapid currents; that the discovery is of vast importance; may be of greatest usefulness in our inland navigation; and, if it succeeds, of which I have no doubt, the value of it is greatly enhanced by the simplicity of the work, which, when explained, may be executed by the most common mechanic.

[1] History of the Steam-Engine, p. 236.

Given under my hand and seal, in the town of Bath, county of Berkeley, in the State of Virginia, his 7th day of Sept., 1784.

GEORGE WASHINGTON.

John Fitch was an ingenious Connecticut mechanic. In April, 1785, as Fitch himself states, at Neshamony, Bucks County, Pa., he conceived the idea that a carriage might be driven by steam. After considering the subject a few days, his attention was led to the plan of using steam to propel vessels, and from that time to the day of his death he was a persistent advocate of the introduction of the steamboat. At this time, Fitch says, "I did not know that there was a steam-engine on the earth;" and he was somewhat disappointed when his friend, the Rev. Mr. Irwin, of Neshamony, showed him a sketch of one in "Martin's Philosophy."

Fitch's first model was at once built, and was soon after tried on a small stream near Davisville. The machinery was made of brass, and the boat was impelled by paddle-wheels. His own account of his invention is as follows:—

PHILADELPHIA, December 8, 1786

To the Editor of the Columbian Magazine.

SIR,—The reason of my so long deferring to give you a description of the steam-boat has been in some measure owing to the complication of the works, and an apprehension that a number of drafts would be necessary in order to show the powers of the machine as clearly as you would wish. But as I have not been

able to hand you herewith such drafts, I can only give you the general principles. It is in several parts similar to the late improved steam-engines in Europe, though there are some alterations. Our cylinder is to be horizontal, and the steam to work with equal force at each end. The mode by which we obtain what I take the liberty of terming a vacuum is, we believe, entirely new, as is also the method of letting the water into it, and throwing it off against the atmosphere without any friction. It is expected that the engine, which is a twelve-inch cylinder, will move with a clear force of eleven or twelve hundred weight after the frictions are deducted; this force is to act against a wheel of eighteen inches diameter. The piston is to move about three feet, and each vibration of the piston gives the axis about forty evolutions. Each evolution of the axis moves twelve oars or paddles, five and a half feet, which work perpendicularly, and are represented by the stroke of the paddle of a canoe. As six of the paddles are raised from the water six more are entered, and the two sets of paddles make their strokes about eleven feet in each evolution. The cranks of the axis act upon the paddles about one third of their length from the lever-end, on which part of the oar the whole force of the axis is applied. Our engine is placed in the boat, about one third from the stern, and both the action and the re-action turn the wheel the same way.

With the most perfect respect, sir, I beg leave to subscribe myself,

Your very humble servant, JOHN FITCH.

Another of Fitch's boats, in April, 1790, made seven miles an hour. Fitch, writing of this boat, says that "on the 16th of April we got our work completed, and tried our boat again; and, although the wind blew very fresh at the east, we reigned lord high admirals of the Delaware, and no boat on the river could hold way with us." In June of that year it was placed as a passenger-boat on a line from Philadelphia to Burlington, Bristol, Bordentown, and Trenton, occasionally leaving that route to take excursions to Wilmington and Chester. During this period, the boat probably ran between two thousand and three thousand miles, and with no serious accident. During the winter of 1790-1791, Fitch commenced another steamboat, the "Perseverance," and gave considerable time to the prosecution of his claim for a patent from the United States. The boat was never completed, although he received his patent, after a long and spirited contest with other claimants, on the 26th of August, 1791, and Fitch lost all hope of success. He went to France in 1793, hoping to obtain the privilege of building steam-vessels there, but was again disappointed, and worked his passage home in the following year,[1] and later brought out a new boat in New York City driven by a screw-propeller. It seems to have been customary to secure a witness in those days as in our own, and we have the following.

This may certify that the subscriber has frequently seen Mr. Fitch's (John Fitch) steamboat, which with

[1] History of the Steam-Engine, p. 240.

great labour and perseverance he has at length completed; and has likewise been on board when the boat was worked, against both wind and tide with considerable velocity, by *the force of steam only*. Mr. Fitch's merits in constructing a good steam-engine, and applying it to so useful a purpose, will no

Fig. 5.—John Fitch, 1788.

doubt meet with the encouragement he so richly deserves from the generosity of his countrymen, especially those who wish to promote every improvement of the useful arts in America.

(Signed) DAVID RITTENHOUSE.

PHILADELPHIA, Dec. 12, 1787.

Fitch finally retired to a farm, which he pre-empted from the public lands, in Kentucky, and there died

in 1798, and was buried with a model of his steamboat beside him.

Mr. Wm. A. Mowry thus states another historical fact:[1] "After Watt had invented the steam-engine, Captain Samuel Morey, of Orford, N. H., was fully persuaded that the power of steam could be applied to propelling boats by the means of paddle-wheels. He therefore set himself to the task of inventing a boat to be thus propelled by steam. This he accomplished. He made the boat, built the steam-engine, put in the necessary machinery, and with a single companion, if not entirely alone, made his first trial-trip with complete success, running from Orford, on the Connecticut River, to Fairlee, Vt., and returning to Orford. This was as early as 1793, probably in 1792, although one writer says 1790, — at least fourteen years before Fulton's trial-trip in the 'Clermont' up the Hudson, and nine years before his first trial-boat was constructed in France."

Another interesting illustration of the frequently observed fact that a common thought often either simultaneously comes to the minds of many men, or passes, like the electric current, from one to another, when circumstances and a favourable route of communication permit, is seen in the entrance upon the scene at about this time of John Stevens, of New Jersey. It is said that, driving along the bank of the Delaware, he suddenly came in sight of the little steamboat of Fitch, which that inventor was just then running between Bordentown and Philadelphia, and at once deter-

[1] Providence Journal, 1874.

mined that he could and would accomplish that, as yet, only partially completed task. Returned home, he at once set about the construction of engine and boat; and after several years of intermittent labour brought, in 1804 and 1805, two forms of engine and boilers, and two boats, in which he adopted the screw as the propelling instrument, employed high-pressure steam-engines, and attained a speed which has been variously reported as from four to eight miles an hour. He invented the "sectional" or "safety" boiler, and when Watt was still using steam at a pressure not exceeding seven pounds per square inch, he regularly operated his engines at fifty and upward. The machinery of his first boat is still preserved in excellent condition by his heirs. Later, 1807–1809, he built larger and faster boats, and adopted in their construction the common paddle-wheel and appropriately constructed engines.

Meantime the work was going on slowly but steadily on the other side the Atlantic, in the home and birthplace of the steam-engine. After the time of Hulls we meet with no authentic accounts of such inventions or experiments until about the time that Fitch began his work, when, in 1786 or 1787, Patrick Miller, of Dalswinton, built a boat in which he used manual power to turn paddle-wheels. A young student, tutor to his sons, then suggested the use of steam-power, and soon after published an account of his scheme (1787), asserting that he "had reason to believe" that the steam-engine might thus be made useful. Miller, Taylor, and a young mechanic,

William Symmington, the inventor of a new form of steam-engine, finally entered into an arrangement resulting in the construction, in 1788, of a boat (Figure 6) only twenty-five feet long, of seven feet beam, and of rude form, which was reported to make five miles an hour.

Fig. 6. — Miller, Taylor, and Symmington, 1788.

From what follows, this would seem to have been a vessel with a divided or "catamaran" form of hull:[1] —

DUMFERLINE, 6th of June, 1789.

GENTLEMEN, — The bearer, Mr. William Symington, is employed by me to erect a steam-engine for double vessel, which he proposes to have made at Carron. I have therefore to beg that you will order the engine to be made according to his directions,

[1] Preble on Steam Navigation, p. 20.

As it is of importance that the experiment should be made soon, I beg also that you will assist him, by your orders to the proper workmen, in having it done expeditiously. I am, ever, with great regard, gentlemen, your most obedient, humble servant,

PATRICK MILLAR.

To the CARRON COMPANY, Carron.

In the following year, a larger and still more successful vessel was built, and a speed of seven miles an hour was attained. Nothing came of this success, however, and the partnership was dissolved. Later, Symmington went to Lord Dundas, who supplied him with capital, and in 1801 began the construction of the "Charlotte Dundas," — a paddle-steamer driven by horizontal engines, and sufficiently powerful to serve as a towboat on the canals, and having a speed, running free, of five to seven miles an hour.

In France, also, the application of steam to navigation was experimentally attempted at a still earlier date. In 1770, according to Figuier, the Comte d'Auxiron and his friend, the Chevalier Mounin, supported the inventor, the Marquis de Jouffroy, in his attempt to build a steam-vessel. According to our author,[1] —

"D'Auxiron determined to attempt the realization of the plans which he had conceived. He resigned his position in the army, prepared his plans and drawings, and presented them to M. Bertin, the Prime Minister, in the year 1771 or 1772. The Minister

[1] History of the Steam-Engine, p. 232.

was favourably impressed, and the King (May 22, 1772) granted D'Auxiron a monopoly of the use of steam in river-navigation for fifteen years, provided he should prove his plans practicable, and they should be so adjudged by the Academy.

"A company had been formed the day previous, consisting of D'Auxiron, Jouffroy, Comte de Dijon, the Marquis d'Yonne, and Follenai, which advanced the requisite funds. The first vessel was commenced in December, 1772. When nearly completed, in September, 1774, the boat sprung a leak, and one night foundered at the wharf.

"After some angry discussion, during which D'Auxiron was rudely, and probably unjustly, accused of bad faith, the company declined to advance the money needed to recover and complete the vessel. They were, however, compelled by the court to furnish it; but meantime D'Auxiron died of apoplexy, the matter dropped, and the company dissolved. The cost of the experiment had been something more than fifteen thousand francs.

"The heirs of D'Auxiron turned the papers of the deceased inventor over to Jouffroy, and the King transferred to him the monopoly held by the former. Follenai retained all his interest in the project, and the two friends soon enlisted a powerful adherent and patron, the Marquis Ducrest, a well known soldier, courtier, and member of the Academy, who took an active part in the prosecution of the scheme. M. Jacques Périer, the then distinguished mechanic, was consulted, and prepared plans, which were adopted

in place of those of Jouffroy. The boat was built by Périer, and a trial took place in 1774, on the Seine. The result was unsatisfactory. The little craft could hardly stem the sluggish current of the river, and the failure caused the immediate abandonment of the scheme by Périer.

"Still undiscouraged, Jouffroy retired to his country home at Baume-les-Dames, on the river Doubs. There he carried on his experiments, getting his work done as best he could, with the rude tools and insufficient apparatus of a village blacksmith. A Watt engine and a chain carrying "duck-foot" paddles were his propelling apparatus. The boat, which was about forty feet long and six wide, was started in June, 1776. The duck's-foot system of paddles proved unsatisfactory, and Jouffroy gave it up, and renewed his experiments with a new arrangement. He placed on the paddle-wheel shaft a ratchet-wheel, and on the piston-rod of his engine, which was placed horizontally in the boat, a double rack, into the upper and the lower parts of which the ratchet-wheel geared. Thus the wheels turned in the same direction, whichever way the piston was moving. The new engine was built at Lyons, in 1780, by Messrs. Frères-Jean. The new boat was about one hundred and fifty feet long and sixteen wide; the wheels were fourteen feet in diameter, their floats six feet long, and the "[illegible]," or depth to which they reached, was about two feet. The boat drew three feet of water, and had a total weight of about one hundred and fifty tons.

"At a public trial of the vessel at Lyons, July 15,

1783, the little steamer was so successful as to justify the publication of the fact by a report and a proclamation. The fact that the experiment was not made at Paris was made an excuse on the part of the Academy for withholding its indorsement, and on the part of the Government for declining to confirm to Jouffroy the guaranteed monopoly. Impoverished and discouraged, Jouffroy gave up all hope of prosecuting his plans successfully, and re-entered the army. Thus France lost an honour which was already within her grasp, as she had already lost that of the introduction of the steam-engine in the time of Papin."

During the whole of the last quarter of the eighteenth century, invention was thus rife all over the then civilized world; and by the end of that century success was in sight of a dozen inventors on either side the Atlantic. The attention of statesmen like Stevens, Livingston, and others had begun to be attracted to the importance of the new motor for this purpose; and the great mechanics of every nation were seeking the best methods of construction and application of a marine engine. In the United States, Nicholas Roosevelt built a boat on the Passaic, in 1798, sixty feet long, and put into it an engine of twenty inches diameter of cylinder, driving the craft eight miles an hour on the occasion of a trial trip on which a large party of invited guests were entertained. Livingston and Stevens had both employed Roosevelt in building engines for themselves, and their later activity in this direction was undoubtedly stimulated still further by his operations. It was at this date

that Livingston obtained from the State of New York the exclusive right to the steam-navigation of the waters of that State, which, including as they did the Hudson River, gave him a most important monopoly, conditioned, however, upon his success in the production within a year of a steamboat that should have a speed of not less than four miles an hour. The act expired through this limitation; but in 1803 he secured its re-enactment, and by the aid of Robert Fulton, who now comes forward as the prominent figure, he became one of the great agents in the final and permanently successful introduction of the steamboat.

CHAPTER III.

ROBERT FULTON'S EARLY LIFE.

Robert Fulton, artist, engineer, mechanic, inventor, prophet, and statesman, was a genius of the first magnitude. His later fame is, as in so many such cases, based rather upon what became most familiar in his career than upon the real capacity and talent of the man. His achievements in the introduction of steam-navigation were by no means the best or highest measures of his genius. He was an inventor, and a great one; but he did not invent the steamboat, or, so far as is known, any part of it. He was a talented artist, but his renown does not in the least rest on his fame on that score; he was a civil engineer, and accomplished in that branch of the constructive profession, but the fact is to-day almost unknown even to members of his craft; he was an eminent mechanic, but the "Clermont" — his first steamboat in America — did not illustrate his genius in that direction.

The grand achievement of Fulton was the direction of an enterprise which resulted in the production by Watt and his partners in Great Britain, and by Brown in New York, of a steamboat that could give commercial returns in its actual daily operation, and the institution of a "line" of boats between New York and

Albany, the success of which insured the introduction and continued operation of steam-vessels, with all the marvellous consequences of that great event. He was a prophet, inasmuch as he foresaw the outcome of this grand revolution, in which he was so active a participant and agent; and he was a statesman, in that he weighed justly and fully the enormous consequences of the introduction of steam-navigation as an element of national greatness; but he has been recognized neither as prophet nor as statesman, both of which he was, but as the inventor of the steamboat, — which he was not.

Fulton was born at Little Britain, Lancaster County, Penn., in 1765. He was of Irish descent, his father having come from Kilkenny when quite a young man. The Fultons had, although living in the then wilderness, distinguished families for their neighbours. The family of Benjamin West lived in the adjacent county; and the home of William Henry, close by, was a rendezvous for many interesting and stimulating acquaintances and a most enjoyable society. The Fulton farm was sold to Mr. Swift in 1766, and the family removed to the city of Lancaster, in which place the father died in 1768, leaving his widow with five children to be cared for, and very little property with which to provide for them.

Robert was sent to school in 1773, and acquired the rudiments of a good English education, having, however, learned to read, to write, and to "cipher" already at home. He was not a brilliant scholar, but made fair progress, though he was vastly more inter-

ested, as are all bright boys of that age, in what was going on in the workshops of the mechanics with whom he was acquainted. On one occasion, his mother having suggested to his teacher that the boy was not giving as close attention to his books as was desirable, the honest pedagogue replied that he had done his best, but that Robert had asserted that "his head was so full of original ideas that there was no room for the storage of the contents of dusty books." The boy was then ten years old.

Even at this early age he exhibited clearly the bent of his genius by the manufacture of his own lead-pencils, — hammering out the lead from bits of sheet metal that came in his way, and made pencils which were considered hardly inferior to any graphite pencils of that time. This was two hundred years after their invention; but the Fabers had been making graphite pencils a dozen years, and the Conté process, now standard, was only invented twenty years later. It may be very possible that Fulton made a good pencil for his time. In 1778, the citizens having been forbidden by the town council to illuminate in honour of Independence Day because of the scarcity of candles, Robert invented a sky-rocket, and, as he said, proposed to illuminate the heavens instead of the streets. When it was suggested to him by a friend that this was impossible, he replied, "No, sir; there is nothing impossible."

Fulton while still a child became an expert gunsmith, and supplied to the makers in his town drawings for the whole, — stock, locks, barrels, and all, and

made computations of proportions and performance that were verified on the shooting-range. He was successful, both as designer of the main features of the gun and in his decorative work, and the makers were always glad to secure his sketches, and to profit by his computations. He designed an air-gun in 1779, at the age of fourteen, but with what success is not known.

It was at about this time that his first thought of new methods of boat-propulsion seem to have come to him. Finding the labour of "poling" a flat-bottomed boat, on the occasion of making a fishing excursion, somewhat arduous, he made a model of a boat to be impelled by paddle-wheels. In 1779, he tried his scheme on the same old fishing-boat which had so severely taxed his powers, and found it so satisfactory that he and his comrade used it a long time on their fishing excursions on the Conestoga, about Rockford, the residence of his comrade.

The boy's childhood and youth included the preliminaries to the War of the Revolution and its final successful accomplishment, and the young engineer and artist was one of the most earnest of rebels, and an honest foe of the Tories, many of whom were settled in his neighbourhood, where were quartered, for a long time, a body of the Hessian troops sent over by the British government. These events naturally turned the thoughts of the young inventor to warlike devices and military and naval inventions; and his whole later career was, not improbably, influ-

enced greatly, if not absolutely controlled, by the bent thus given his fertile brain and active mind.

Meantime the genius of painting grew strong within him; and the development of that natural talent had become so unusual and so promising that, at the age of seventeen, Fulton thought it wise to seek a wider field for the employment and application of his time and labour. He went to Philadelphia in 1782, and there remained four years, returning to Lancaster on his twenty-first birthday. He supported himself in the interval with his pencil, and proved himself capable of doing good work in making drawings of machinery, as well as in painting landscapes. He was not only able to care for himself, but was so successful that he brought back to his mother the means of purchase of a small farm in Washington County, Penn., where he settled his mother and her family, giving her a deed of the property. Meantime, also, he had made the acquaintance of Benjamin Franklin, — then about to be sent to the Court of France, — and of other distinguished citizens of that metropolis, and had thus, by a succession of happy accidents, laid the foundation of his later fortunes.

But close confinement and intense application had enfeebled his strength, and his health began to fail, his lungs showing symptoms of such weakness that it was considered unsafe to neglect them, and his friends insisted upon his going abroad for travel, and in search of diversion, recreation, and health. His old friend, Benjamin West, had already settled in London, and had there become famous; and it was thought that

he and other acquaintances of the promising young artist would be able to serve him in many ways, and help him secure advantageous positions and employment. He first went for a time to the Warm Springs, Virginia, and passing safely through an illness involving the lungs in a state of serious inflammation, and a period in which incipient hemorrhages were among the more unpromising symptoms, he finally became well enough to undertake the voyage, and sailed for England some time in 1786.

We have few authentic accounts of Fulton's life in the mother country. He spent some time in London with his friends, including Benjamin West, who received him most kindly, and continued an earnest and helpful friend during the remainder of his life. He was employed mainly in painting, but did not lose his interest in mechanics and scientific pursuits. He became acquainted with the Duke of Bridgewater, and with Lord Stanhope, and this friendship led to many schemes for the promotion of the useful arts through the application of Fulton's and other's inventions. Fulton's own success was great; but this did not prevent his admiring, as an artist only could, the work of his master, West. He endeavoured to secure the whole series of West's paintings for the city of Philadelphia, and entered into correspondence with his friends at home, with this object in view, and with the consent of the great painter, who was ready to dispose of the collection at what was regarded as a very moderate price, — much less than he received for his larger and most esteemed single paintings a little

later. But Fulton was unable to raise the funds at home, and the opportunity was lost.

Fulton went across the Channel and took up his residence in Paris in the year 1797, probably led to do so in the expectation that he might there find an opportunity to bring out some of the numerous inventions which were teeming in his uneasy brain. He was most hospitably received by the American minister, Mr. Barlow, and his wife; and immediately upon the opening of their house and their establishment there, they invited Fulton to join them, greatly to his satisfaction. He accepted the kind proposal, and lived in their family seven years, practising his profession, as artist, learning the European languages, and studying the natural sciences, while at times endeavouring to find ways of putting into practical operation his schemes for improvement of various kinds of machinery.

During the few years of his residence in England, Fulton's mind had been as active in the devising of new schemes and inventions as during his boyhood and youth at home. As early as 1793, according to Colden, his biographer, he had conceived the idea of applying the engine of Watt to the propulsion of steam-vessels, and his manuscripts of that time contain confident assertions of its practicability. He patented, in 1794, a contrivance which he calls a "double inclined plane" for use in transportation; and while living in Birmingham, at that time or a little later, contrived various new machines and apparatus of engineering. The manuscripts containing accounts of

these plans was lost, some years later, in 1804, when shipped from Paris to the United States; the vessel in which they were sent was wrecked, and the papers were ruined by submersion before they could be rescued. In the year 1794, also, which seems to have been a period of very great activity with him, he patented a marble-sawing machine, for which he afterward received the medal of the Society for the Promotion of the Arts, and the thanks of the society as well. His next invention seems to have been a machine for spinning flax; another was a rope-making machine; and still another a mechanical dredger or power-shovel,— the latter coming into use, and remaining for a long time a common machine in England.

Fulton had by this time given up his portrait painting, and thenceforward it was only the amusement of his hours of leisure or of relaxation from his labours as a civil engineer; the formal announcement of which fact was made about 1795, at which date he published a Treatise on Canal Navigation. He described a number of very ingenious devices in improvement of the then common methods and apparatus of locks and other accessories of the canal. In making the illustrations, he illustrated as well his own skill in drawing, and his own power of designing details of his machinery. Copies of his work were sent to the governor of the State of Pennsylvania and to General Washington, whose reply expressed much interest in the subject, and confidence in the final adoption of some such system of general intercommunication in the United States. His letter to

the governor of his native State, published in his book, exhibits a thoroughly statesmanlike quality of mind, and broad as well as liberal views.

Fulton's visit to France was made largely with the hope of securing his patents on these canal improvements, and of introducing his inventions in that country. He wrote one of his political essays in the form of a letter to Lord Stanhope, in 1798, in which he endeavoured to show the importance of public improvements, of domestic manufactures and trade, and of simple and light taxation. His idea was, as he said at the time, to secure the publication of these views, not only for the advantage of the people of Great Britain, but with the hope that they might precede him on his return to his own country, and enable him to effectively urge similar views upon the public men and legislators in America, and to develop a public sentiment in favour of what he considered essential and correct views of general economics.

Fulton was unquestionably not only thinking much on the economical problems of his time, and of general statecraft, but he was as undeniably exhibiting the grasp of the statesman upon all such great questions. He wrote a letter "to the Friends of Mankind," especially addressed to the French legislature, in which he treated such topics with ingenuity, intelligence, and force. It was at a time when the whole world was agitated by the events which preceded the French Revolution, and when the French themselves were seeking, however blindly and mistakenly, with all earnestness and good intent, the way to better

methods of government and of national life. They had already inaugurated that grand system of public education, of technical and trade-education, which in their hands, and, especially in later years, in those of the Germans, has grown so marvellously, and with such splendid results, during the intervening century, now just ending. Fulton reinforces the lesson already learned, and insists upon the essential necessity of such general and practical education, of promoting interior improvements, and all those vital works upon which the prosperity of a country depends so directly. He says, "The whole interior arrangements of governments should be to promote and diffuse knowledge and industry; their whole exterior negotiations to establish a social intercourse with each other, and to give free circulation to the whole produce of virtuous industry."[1] He was a pronounced and ardent free-trader; and his most warlike acts, his greatest inventions in the military and the naval arts, were intended to promote the cause of free-trade by driving from the ocean the fleets of all nations seeking to control the high seas for their own exclusive purposes, in order that he might thus aid in securing that safety against aggression which is the essential prerequisite of universal freedom of exchanges. "He considers what he calls the war system of the old world as the cause of the misery of the greatest portion of its inhabitants, and this leads him to a curious investigation of its effects."[2] His "Thoughts on Free

[1] Colden's Life of Fulton, p. 22.

[2] Ibid., p. 23.

Trade" follow the same line of study. In this little tract, still unpublished, he developed his ideas at some length, seeking to show that foreign possessions and taxes on imports are necessarily injurious to nations. It is dated 1797; but there is no evidence that it was ever published, or ever presented to the French government in any form. He was at this time endeavouring to impress his views upon Carnot, — the greatest statesman of his time, then the representative, in a family of men of genius, of the better ideas of the revolutionary period, — and to obtain through him some recognition of what he thought right principles of administration, and which were, in his view, essential to the promotion of the best interests of the people. When Carnot was compelled to leave Paris, at the inauguration of the new government, Fulton laid his plans before the Directory; but they do not appear to have influenced that body, and seem to have remained unnoticed.

Fulton's conclusion was: — "After this I was convinced that society must pass through ages of progressive improvement before the freedom of the seas could be established by an agreement of nations that it was for the true interest of the whole. I saw that the growing wealth and commerce of the United States, and their increasing population, would compel them to look for a protection by sea, and perhaps drive them to the necessity of resorting to European measures by establishing a navy. Seeing this, I turned my whole attention to finding out means of destroying such engines of oppression by some

method which would put it out of the power of any nation to maintain such a system, and would compel every government to adopt the simple principles of education, industry, and a free circulation of its produce." Thus it was the statesman in the portrait-painter that led him to apply his great genius as an inventor and as a mechanic to the production of new means of protecting the people, their industries, their lives, their liberties, through the novel applications of the useful arts, and guiding their genius in invention and construction, first to defence, then to better methods of production and more efficient industry. Fulton was statesman, as well as artist, mechanic, engineer, economist, inventor.

IV.

THE ARTIST AS ENGINEER.

ROBERT FULTON was an artist in the best sense of that term; and, like all great painters or sculptors, like all men of genius who accomplish anything by actual *doing*, he was as naturally and truly a mechanic. The artistic sense has little value for purposes of accomplishment without manual and tactual dexterity and sensitive nerves and muscles in exact accord with the operations of the thought-faculty. Every successful artist, like every surgeon, investigating chemist, physicist, naturalist of whatever type, depending on manipulative operations for his triumphs, must be naturally a mechanic, with all the mechanic's intuitions largely developed. He must be a constructor as well as a thinker, and must be able to do, as well as to imagine beautiful things. All this was in Fulton, and in such degree that he turned his mind with the greatest facility from the creations of the artist to the constructions of the engineer and the mechanic. He found it as easy to take up the drawing instruments of the engineer as the pencil of the painter; as easy to devise new forms of road, canal, ship, or machine as new and lovely pictures of landscape, or to depict human features in all their wonderful modes of expression, and to illustrate

all their marvellous shades of character. The successful artist was even more successful as engineer.

The genius of the engineer and the originality of the inventor, which has been seen in the boy of fourteen, developed with his growth, and without interruption, into his mature years. The sketches made for the gunmaker of his native town were but the prototypes of the drawings of the greater works of the engineer and of the mechanic. The invention of the sky-rocket was the antecedent of the invention of a submarine engine-of-war; the little paddle-boat on the Conastoga was the symbol of the later steamboat on the Seine and on the Hudson; and the boy inventor was the parent of the man as engineer. But the genius which had been, in youth, guided and given direction by the whims of the child, in later years was made the servant of the sage; and the grander plans of the statesman, devised with a view to the amelioration of the trials of humanity, were promoted effectively by the application of the same genius to their accomplishment. The glory of the inventor is the greater that it came of the grander thought of the humanitarian.

Fulton's work as engineer appears to have been both extensive and successful. His attention seems to have been called at an early period in his professional career to the extension and improvement of canals. The floods of 1795 in Great Britain, where he was then residing, destroyed much property, and seriously injured portions of the Shrewsbury Canal, especially in the neighbourhood of Long, where it was

carried over the Tern on an aqueduct of some magnitude. Fulton at once set about the study of better methods of construction, and devised many ingenious forms of apparatus and machinery for use in canal construction and operation. He proposed, in 1796, a cast-iron aqueduct, of which he submitted complete plans and working drawings to a committee of the Board of Agriculture, in March of that year. He proposed the use of castings which, as he said, could be "cast in open sand," and erected without other than the simplest and most inexpensive kind of staging, instead of the elaborate centring necessitated by construction of stone arches, — a detail of the older construction which often cost more time and more thought in planning, and proved hardly less costly in building, than the main structure itself after its completion. He showed that his plan compelled the making of but few patterns, and those of easy and cheap construction; and that the difficulties of securing a water-tight lining so great in stone works of this sort, were, with iron, insignificant. In case of a leak occurring later, it would be easily and quickly detected, and as readily and certainly staunched; while in stone it often was not observed until much damage had been done; and its repair was sometimes a matter of great difficulty, delay, and expense.

One of these aqueducts of cast-iron was afterward erected, on the plan of Fulton, over the Dee, at Pontcylytee, twenty miles from Chester, composed of eighteen spans of fifty-two feet each, and supported on pillars, the tallest of which, in the middle of the val-

ley, was one hundred and twenty-six feet high. The total length of the structure was about three hundred and twenty-nine yards, its width twenty feet, and its depth six feet. The tow-path was secured on one side, bracketed to the body of the aqueduct, and rendered safe by means of a strong iron rail.

The same principles were adopted in the preparation of plans for bridges of various kinds, and for all purposes; and plans, detail drawings, and models were exhibited to the Board of Agriculture at about this time, for canals, railways, — then already in existence, though before the days of steam locomotion and of the substitution of the steam-horse for animal power,— and for highways. Several of these bridges were erected on the line of the Surrey Iron Railway, including one at Wandsworth. Bridges were designed by Fulton for carrying the roads across deep and wide valleys on inclined gradients; and in such cases, often, he proposed to haul them over by means of endless ropes, instead of sending the horses over with them on tow-paths attached to the bridge, or forming part of it. Water-power or other efficient motor was to be employed where convenient. The modern and now usual system of discharging from the railway into barges or vessels by dumping the load from the cars or wagons into a slide leading down to the water-side from the higher level of the road, was one of the plans here introduced. Special provisions were made for the passing of roads, water-courses, and other lines of rail, and the whole formed a complete and consistent scheme. Fulton's biographers state that he

always made the most perfect and detailed plans, the neatest of drawings, and usually very accurate models, before proceeding with his proposals or laying them before capitalists or public officials. His computations of costs were equally exact, detailed, and well planned, giving the expense of details of construction, foot by foot, all dimensions, the loads to be carried for a single horse, the speed, the profits, and the estimated revenue.

One of Fulton's most interesting and novel, if not his most daring of innovations, was that in which he proposed to take his boats out of the canal and transport them overland at certain parts of the route, to avoid the first cost of construction of a canal in a difficult country. These "inclined planes" were actually built, and were found practicable; and illustrations of this plan have been in use for many years in the United States, on the line of the Morris and Essex Canal and elsewhere, while the great scheme of Captain Edes, of a trans-isthmian railway, uniting the Atlantic and Pacific Oceans, was a development of the same idea on a grander scale. This invention was patented by Fulton in England, in May, 1794. It was proposed that the boats should be either taken upon cradles of suitable form and size or into caissons in which they could float, and the whole mass then drawn out of water on wheels, and up the inclined planes to the higher level, or lowered from the upper to the lower level, as might be required, by horse-power. Counterbalances were adopted to make the total load a minimum, and every device then known was applied

for reducing friction and resistances. Water-power, where available, was to be substituted for horse-power, and brakes were employed to control the load when lowering it. It was proposed that in this manner advantage should be taken of the opportunities occasionally offering to utilize broad streams, or even considerable lengths of rivers, in place of the costly construction of canals, by sending the boats down on the one side and taking them up on the other, or by running for a distance along the thread of the stream, then resuming the course of the canal, transferring from the one to the other by means of inclined planes. The boats were so designed that they could be easily hauled by horse-power, and yet so light that the transfer on the inclined planes should not, even where quite steep, become a serious task. In other cases, he arranged for drawing water from the upper level and sending it down into the lower portion of the canal, utilizing its weight in the passage by employing it in the raising of the boats. In some cases he used centrifugal fans or blowers as regulators of speed.

These plans were, many of them at least, described in a treatise "On the Improvement of Canal Navigation," published in London, in 1796, in 4to size, and illustrated by many neatly-made plates. Several forms of boat for his special purposes are there shown by Fulton, and each adapted to its peculiar purpose, as for rapid or for slow speeds; for marketing or for heavy freighting; for mounting on wheels and transportation overland. He used an elevator

for perpendicular lifts, and described all its details of construction, including a counterbalance, which relieved the hoist from unnecessary strains. This subject occupied the attention of the great engineer throughout the remainder of his life; and later, even while in the midst of the most engrossing labours on the more immediately promising inventions, and while working upon his scheme of steam-navigation, Fulton was able to find an occasional opportunity to give a little leisure to the promotion of canal construction abroad and at home. His treatise on the subject, published in both French and English, called the attention of Mr. Gallatin, later Secretary of the Treasury of the United States, to his work, and he was invited by that gentleman to present his views in detail, for use in a Report to Congress relating to internal improvements.

In his report to the Secretary of the Interior, Fulton exhibits his statesmanlike quality of mind, and some of his most impressive thoughts. He quotes Hume, who says: "The government of a wise people would be little more than a system of civil police; for the best interest of man is industry and a free exchange of the produce of labour for the things that he may require," and goes on to ask "what stronger bonds of union can be invented than those which enable each individual to transport the produce of his industry twelve hundred miles for sixty cents the hundred weight?" He refers to the case of England and Scotland, once enemies, now bound together "by habit, by turnpike roads, by canals, and by reciprocal

interests;" "and when the United States are bound together by canals, by cheap and easy access to a market in all directions, by a sense of mutual interests arising from mutual intercourse and mingled commerce, it will be no more possible to split them into independent and separate governments, each lining its own frontiers with fortifications and troops, to shackle their own exports and imports to and from the neighbouring States, than it is now possible for the government of England to divide and form again into seven kingdoms." And speaking of his ideas and their origin, he says: "It is now eleven years since I have had this plan in contemplation for the good of my country;" and "it contemplates a time when canals shall pass through every vale, winding around each hill, and bind the whole country together in bonds of social intercourse."

On his return to his native country in 1807, Fulton addressed letters to the Government on this subject, and again in 1810 wrote to the legislature of New York on the same subject, acting later as a commissioner to investigate the practicability of securing intercommunication in this manner between the waters of the great lakes and the Hudson. As late as 1814 he was still urging this project, which finally resulted in the construction of the Erie Canal, — a system of public improvements which became ultimately a source of enormous wealth to the country, and of advantage to the State through which it passed.

In a letter to President Madison in 1810 he wrote: "Canals bending around the hills would irrigate the

grounds beneath and convert them into luxuriant pasturage. They would bind a hundred millions of people in one inseparable, compact body, alike in habits, in language, and in interest, — one homogeneous brotherhood, — the most invulnerable, powerful, and respectable on earth." "Will you not search into the most hidden recesses of science," he asks, to find a means "to direct the genius and resources of the country to useful improvements, to the sciences, to the arts, education, the amendment of the public mind and morals?" "In such pursuits lie real honour and the nation's glory;" "such are the labours of enlightened republicans, — of those who labour for the public good."

V.

THE ENGINEER, AS INVENTOR, IN SUBMARINE WARFARE.

WHILE it is true that the genius of Fulton as an inventor was to a certain extent exhibited in his civil constructions, and in his numerous novel devices for the improvement of canals and their navigation, the engineer of to-day would regard them as rather simple and commonplace constructions, and as illustrating the ordinary solution of every-day problems, rather than as the product of remarkable inventive talent. Were there any question of his great skill and talent in this department, however, the study of his plans for the institution of a system of submarine navigation and warfare would thoroughly remove all doubt. In the early part of the century, perhaps before, he had given much thought to the means available for securing what he considered essential to the independence of nations, — the freedom of the seas. These studies finally resulted in the production of a very complete system, both of apparatus and methods, and in the attainment of some success — a very remarkable degree of success for those times — in their application in practice.

Fulton was in France in the year 1803, when he received a message from the British ministry, asking

that he meet an agent of that government in Holland for the purpose of discussing the character and applications of his invention, the general nature of which was fully understood by Lord Stanhope, who had become interested in Fulton and had kept him in view, apparently hoping to secure from him some useful inventions for use in the British army and navy. The inventor proceeded to Holland as arranged; but the agent did not meet his appointment, and Fulton returned to Paris, where he was followed by his intending correspondent in the spring of the year 1804, by whom he was induced to visit London and confer with the new ministry. A commission was appointed in June of the same year, consisting of five distinguished engineers and military men, who examined the plans presented them with interest, but with true British conservatism reported against them as "impracticable." Fulton proceeded at once to demonstrate their entire practicability.

An expedition fitted out against the French fleet in the harbour of Boulogne failed in consequence, not of defects in the torpedoes, but through some inadvertence in their operation by the inexperienced men intrusted with their application. Fulton next conducted experiments illustrating their value and power, blowing up a heavy brig in Walmar roads, beyond Deal, October 15, 1805, under the walls of the castle of Mr. Pitt. Seventy pounds of powder were employed, and the result, as described by the inventor, was perfectly satisfactory: "Exactly in fifteen minutes from the time of drawing the peg and throwing the

carcass into the water, the explosion took place. It lifted the brig almost bodily, and broke her completely in two. The ends sank immediately, and nothing was seen but floating fragments." . . . "In fact, her annihilation was complete, and the effect was most extraordinary." The vessel "went to pieces like a shattered eggshell." Nothing came of his efforts, however, in Great Britain.

The work which had thus attracted the attention of the British government had been in progress, however, for some years in France before Fulton was called to England, and he had already been equally disappointed by the French government. His motto had been, as he afterward expressed it, "The liberty of the seas will be the happiness of the earth;" and his desire was to break up all naval warfare. He was therefore indifferent where or how his enterprise should begin. Naval warfare once rendered impossible, the freedom of the seas was assured, and the liberty and prosperity of his native country to that extent made safe. His first experiments were made at least as early as 1797, when with the aid of Mr. Barlow in Paris he attempted to make a form of what to-day would be called the "automobile," or self moving torpedo. His machine was intended to drive a cigar-shaped torpedo in a definite direction, and to a prescribed place, and there to fire the charge. The experiment was not a success, however; and it was long before he could accomplish anything at all satisfactory to himself. The Fulton "automobile" torpedo was the precursor and the prototype of the

Lay and Howell, the Whitehead, and all the fleet of torpedoes of modern times.

In spite of every discouragement, the great engineer and inventor worked on, seeking ways, as he said, to deliver the world from British oppression by making the high seas free to all. The Directory, however, rejected his plans, and would have nothing to do with his experiments. A change occurred in the outlook the instant the First Consul took his place in the government. He was immediately interested in the plans of the American mechanic, and at once formed a commission, consisting of Volney, La Place, and Monge, all distinguished men, to investigate the schemes to be laid before them. Fulton built a submarine boat during the winter of 1800–1801, and in the following summer invited this commission to witness experiments with it, intending to make it of service in his system of torpedo-warfare.

This "diving-boat," as he called it, seems to have been remarkably successful, judging it by even our modern standards, and is worthy of description.[1]

In the course of his experiments at Brest, Fulton found it to be perfectly practicable to descend to any depth, and to take any course that he might desire. He actually entered channels of twenty-five feet depth and explored their deepest soundings, and was only

[1] Mr. Fulton had directed the whole force of his mind to mathematical learning and mechanical philosophy. Plans of defence against maritime invasion, and of sub-aquatic navigation, had occupied his reflections. During the late war, *he was the Archimedes of his country.* — REIGART.

prevented from attempting greater depths by the fact that he had a boat which would not safely withstand the great external pressure there met. The depth was determined by the use of the barometer, measuring the external pressure, and he directed the course by means of the compass. He found the boat as obedient to the helm under water as above. The air-supply was renewed by drawing upon a reservoir in which was compressed two hundred times its volume of atmospheric air. Using this as a reserve, the inventor was able to remain under water nearly four hours and a half.

St. Aubin's account, as given by Colden, is as follows: "The diving-boat, in the construction of which he is now employed, will be capacious enough to contain eight men, and provision enough for twenty days, and will be of sufficient strength and power to enable him to plunge one hundred feet under water, if necessary. He has contrived a reservoir of air, which will enable eight men to remain under water eight hours. When the boat is above water it has two sails, and looks just like a common boat; when she is to dive, the mast and sails are struck.

"In making his experiments, Mr. Fulton not only remained a whole hour under water, with three of his companions, but had the boat parallel to the horizon at any given distance. He proved that the compass points as correctly under the water as on the surface, and that while under water the boat made way at the rate of half a league an hour, by means contrived for the purpose.

"It is now twenty years," continues St. Aubin, "since all Europe was astonished at the first ascension of men in balloons; perhaps in a few years they will not be less surprised to see a flotilla of diving-boats, which on a given signal shall, to avoid the pursuit of an enemy, plunge under water, and rise again several leagues from the place where they descended.

"The invention of balloons has hitherto been no advantage, because no means have been found to direct their course. But if such means should be discovered, what would become of camps, cannons, fortresses, and the whole art of war?

"But if we have not succeeded in steering the balloon, and even were it impossible to attain that object, the case is different with the diving-boat, which can be conducted under water in the same manner as upon its surface. It has the advantage of sailing like the common boat, and also of diving when pursued. With these qualities it is fit for carrying secret orders, to succour a blockaded fort, and to examine the force and position of the enemy in their harbours. These are sure and evident benefits which the diving-boat at present promises. But who can see all the consequences of this discovery, or the improvements of which it is susceptible? Mr. Fulton has already added to his boat a machine, by means of which he blew up a large boat in the port of Brest; and if by future experiments the same effect could be produced in frigates or ships-of-the-line, what will become of maritime wars, and where will sailors be found to man ships-of-war when it is a physical cer

tainty that they may at every moment be blown into the air by means of diving-boats, against which no human foresight can guard them?"

It was in relation to the plans of this boat that the keen-sighted Napoleon wrote his order for the organization of the commission empowered to examine and report upon Fulton's plans, and of which order the following is the text:—

"I have just read the project of Citizen Fulton, Engineer, which you have sent me much too late, since it is one that may change the face of the world. Be that as it may, I desire that you 'immediately' confide its examination to a commission of members chosen by you among the different classes of the Institute.

"There it is that learned Europe would seek for judges to resolve the question under consideration. A great truth, a physical, palpable truth, is before my eyes. It will be for these gentlemen to try and seize it and see it. As soon as their report is made it will be sent to you, and you will forward it to me. Try and let the whole be determined within eight days, as I am impatient.

"From the Imperial Camp at Boulogne, this 21st July, 1801."

Thus, although his talent as an inventor and his skill as a great mechanic and engineer were not displayed in any remarkable way in the construction of his steamboat, they were exhibited most remarkably in both earlier and later work, and were most wonderfully displayed in all the details of his methods of submarine warfare.

One of the greatest of all inventions was this "diving-boat," in which, like a veritable Captain Nemo, he prowled about beneath the waters of the harbour of Brest during all the summer of 1801, coming to the surface like the gigantic balæna to get breath, plunging beneath it again, rising or diving, moving forward or backward, turning and returning, and after a time coming above water where least expected, and sailing away like any of the commonplace craft with which the harbour was crowded. He spent, at times, several hours below the surface; and once, when a ship was placed at his disposal by Bonaparte, then First Consul, he attacked her from beneath, and blew her into the air with his torpedoes.

Fulton's diving-boat, the "Nautilus," and his powerful torpedoes, kept the British fleet in a state of perpetual apprehension; for it was well known that he was negotiating with the French government for the purchase of his inventions, and had promised Napoleon "to deliver France and the whole world from British oppression."

Dissatisfied with the passive and uncertain character of torpedoes as weapons of submarine warfare, Fulton, although far more successful in their use than any inventor of his own or even the succeeding generation, finally gave up all his experiments, and next turned his attention to the adaptation of heavy ordnance to use under water. Returning to the United States in December, 1806, after nearly twenty years' residence in Europe, and breaking off the fruitless negotiations with the Governments of

France and England, in which he had sacrificed so much time during the previous five years, he presented his plans to the Government of the United States. He received much encouragement from President Jefferson, from President Madison, and from Smith, the Secretary of State and of the Navy under the two Presidents.

According to Colden, in a paper which Mr. Fulton read to certain gentlemen who were appointed by the British ministry in the month of August, 1806, to confer with him, he says: "At all events, whatever may be your award, I never will consent to let these inventions lie dormant, should my country at any time have need of them. Were you to grant me an annuity of £20,000 a year, I would sacrifice all to the safety and independence of my country."

Fulton concludes a letter to Lord Grenville in the following words: "It never has been my intention to hide these inventions from the world on any consideration. On the contrary, it ever has been my intention to make them public as soon as may be consistent with strict justice to all with whom I am concerned. For myself, I have ever considered the interest of America, free commerce, the interest of mankind, the magnitude of the object in view, and the national reputation connected with it, superior to all calculations of a pecuniary nature."

While conducting the correspondence with Jefferson, Fulton wrote a letter describing his "method of firing guns under water." The inventor received a favourable reply from the ex-President; and this letter

is one of those papers which will always possess historical interest, as having formed a part of the most interesting correspondence of those eventful times.

The greatest naval engineer of the generation just passed away improved upon the rude methods and the comparatively feeble apparatus of Fulton; and beside that latest and most formidable of modern engines of war, — the "Destroyer" of Captain Ericsson, — the almost forgotten, the never well-known, devices of the artist-engineer may appear insignificant. Yet when the circumstances by which he was surrounded are remembered, the total lack of all our modern knowledge of the technics of the profession, the absence of all those conveniences that now seem essential to good construction, the absence of all our standard forms of machinery, the inexperience of the workmen who were necessarily intrusted with the carrying out of his plans, and the positively obstructive policy of many departments of government, as well as the opposition of rival claimants of public and private countenance and assistance, — when it is realized how much of talent and how much of enterprise, energy, and persistence were demanded in the accomplishment of such tasks as Robert Fulton so splendidly and successfully undertook, it will certainly be acknowledged that he deserves all the fame that has been accorded him, either as a great mechanic or an ingenious and successful inventor.

The author possesses the autographic copy of the letter to President Jefferson, in 1813, written by Fulton, and left among his papers after his death. The

following is the text, illustrated with pen and ink sketches, here reproduced in fac-simile, precisely as roughly drawn in the hurry of composition or of copying by the inventor, and with all the faults retained.[1]

NEW YORK, June 29, 1813.

THOMAS JEFFERSON, ESQ.

DEAR SIR, — As you take a lively interest in every discovery which may be of use to America, I will communicate one I have made, and on which I have finished some very satisfactory experiments, that promise important aid in enabling us to enforce a respect for our commerce, if not a perfect liberty of the seas. My researches on torpedoes led me to reflections on firing guns under water, and it is about a month since I commenced a suit of experiments.

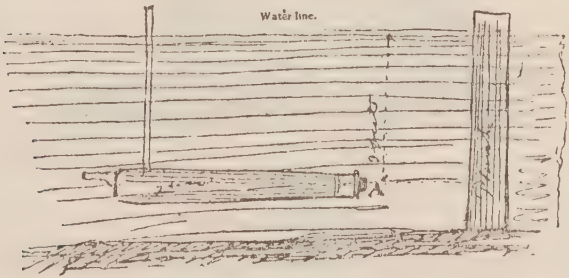

Fig. 1. — First Experiment.

FIRST EXPERIMENT.

A gun 2 feet long, 1 inch diameter, was loaded with a lead ball and one ounce of powder; I put a

[1] This letter was published, with the consent of the present owner, in Scribner's Magazine, August, 1881.

tin tube to the touch-hole, made it water-tight, and let it under water 3 feet. Before it I placed a yellow-pine plank, 4 inches thick, 18 inches from the muzzle. On firing, the ball went through the 18 inches of water and the plank. When the gun is loaded as usual, a tompkin or plug is put in the muzzle, to keep the water out of the barrel, as at *A*. In this experiment the gun being immersed, with the pressure of three feet of water on all its parts, that circumstance might be assigned as a reason for its not bursting. It then became necessary to try the effect with the muzzle in water and the breech in air.

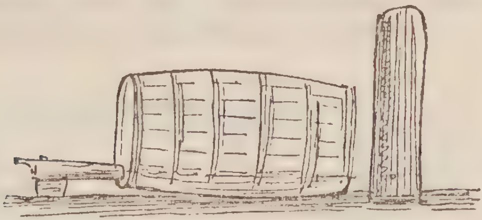

Fig. 2. — Second Experiment.

SECOND EXPERIMENT.

I procured a common wine pipe and inserted the gun, loaded as before, into one end, near the bottom; the muzzle in the wine pipe 6 inches, the breech out 18 inches. The pipe was then filled with water to the bunghole, having a head of water of 2 feet 3 inches above the gun, and a body of water three feet long, through which the bullet had to pass. I then placed the opposite end of the pipe against a yellow-

pine post, in such manner that if the ball went through the water and pipe, it should enter the post. *I fired.* The ball passed through the three feet of water, the end of the pipe, and 7 inches into the post; the cask was blown to pieces, the gun not injured.

Third Experiment.

I obtained a cannon, — a 4-pounder, — for which I cast a lead ball that weighed 6 pounds 2 ounces; the charge $1\frac{1}{2}$ pounds of powder. I placed it under water 4 feet, fired at a target distant 12 feet. The ball passed through the 12 feet of water, and a yellow-pine log 15 inches thick; the gun not injured.

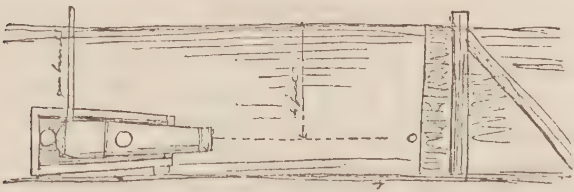

Fig. 3. — Fourth Experiment.

Fourth Experiment.

I put an air box round the same cannon, except one foot of the muzzle, so that the muzzle might be in water, the breech in air, then let it under water 4 feet, and fired as before through 12 feet of water and 15 inches of yellow-pine; gun not injured.

Fifth Experiment.

I ordered a frame to be made of two pine logs, each 13 inches square, 45 feet long, on one end of which I placed a columbiad carrying a ball 9 inches diameter, 100 pounds weight. On the other end I erected a target 6 feet square, 3 feet thick, of seasoned, sound oak, braced and bolted very strong, thus.

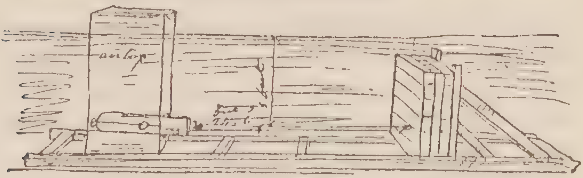

Fig. 4. — Fifth Experiment.

The columbiad, except two feet of the muzzle, was in an air box, the muzzle 24 feet 6 inches from the target, the charge of powder 10 pounds. When fired, the ball entered only 9 inches, — that is, its diameter, — into the oak; the columbiad not injured. This experiment proved the range of 24 feet 6 inches through the water to be too great.

Sixth Experiment.

I took away the columbiad and box, and put a 24-pounder in its place, loaded with 9 pounds of powder, the muzzle 22 feet from the target. On firing, it entered the target only its diameter, — that is, about 6 inches. Without mathematical experience,

the conclusion would have been that the 24-pounder, having a quantity of powder equal to near one half the weight of the ball, and the ball, 5½ inches diameter, presenting little more than one third the resistance to the water and wood that was presented by the 9-inch ball, it should have entered further into the target. *It did not;* momentum was wanting.

Seventh Experiment.

I loaded the columbiad with 12 pounds of powder, and placed the muzzle 6 feet from the target, the muzzle of the gun 2 feet under water; the place where the ball struck the target 5 feet under water. In this case, the ball went through the target 3 feet thick, and where is not known; the target was torn to pieces. In this experiment I fortunately proved beyond a doubt that columbiads can drive balls of one hundred pounds weight through six feet of water and the side of a first rate man-of-war.

On examining Doctor Hutton's experiments and theory of projectiles *in air,* and comparing the density of air with water, the theory is that the columbiad fired might have been 10 feet from the target; the ball would then have struck with a velocity of 650 feet a second, and have passed through 3 feet of oak. Had the columbiad been 16 feet long, and made of a strength to fire with 20 pounds of powder, the range might have been 15 feet through water. But I will take the medium distance of 10 feet, and then the first undeniable principle is, that one vessel can range alongside of another within 10,

or 6, or even 5 feet, when giving the broadside of only two 9-inch balls through the side of the enemy, 8 feet below her water-line. The water would rush in with a velocity of 16 feet in a second, and sink her in 20 or 30 minutes; but from what I have seen in this sluggish kind of shot, I believe if they were put in about 5 feet from each other they would destroy timbers between the two points of shock, and open a space of many square feet, as thus. To put this discovery of submarine firing into

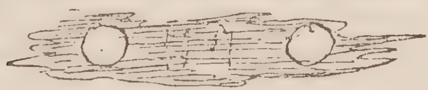

Fig. 5.

practice against the enemy, I have invented a mode for placing my columbiads in ships, from 4 to 8 feet below the water-line, as in the following drawing.

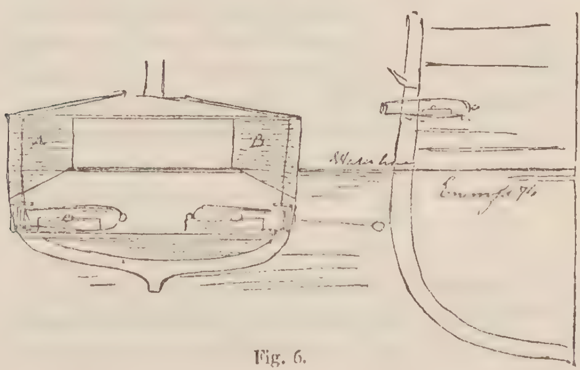

Fig. 6.

My guns are to be cast with two rims round the muzzle, thus. The space *a*, *b*, to be woulded with

Fig. 7.

hemp, and covered with thick leather; the gun then forms a piston like that of a steam-engine or the piston of a forcing-pump. The gun so prepared, there is a brass cylinder, with a strong head, cast, and bored, and bolted in the side of the vessel. When, as in Figure 8, the gun is run into this cylinder, it fits it exactly as the piston does a pump; then if the caliber of the gun be 9 inches diameter, there must be a hole through the bottom of the cylinder of 11 inches, as at *C*, to let the bullet pass, which hole is covered with a strong sliding valve, the axis of which comes inside of the vessel, as at *D*; when the gun is run into the cylinder and ready to be fired, the valve opens. On firing, the gun recoils, shuts the valve, and stops out the water. Thus my guns can be loaded and fired under the water-line with near the same ease they are now worked above the water-line. My present idea is to have four columbiads on each side of a vessel,

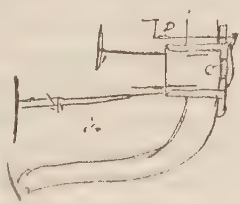

Fig. 8.

and two in her bow, so that, whether she runs bow or side on to the enemy, the bullets must pass through her, as in Figure 9. You will observe, in these sketches, that not using guns above the water-line, I have no port-holes, and the sides above the water may be 7 or 8 feet thick, of pine logs, which renders them not only bullet-proof, but the vessel so buoyant that she cannot be sunk in this manner. My men who work the guns are out of danger under the water-line, and those who steer or work the sails are guarded by walls of wood, as *A*, *B*, Figure 6. For

Fig. 9.

harbour defence, and perhaps finally for service, I have combined a steam-engine with this kind of vessel, to bring her up to the enemy in a calm, or light breezes. In harbours I would not use masts or rigging; there would be nothing to shoot away, nor to hold by in case of attempts at boardage; and in such case, as my deck would not be wanted for fighting or any other purpose, *while in action* I could make it inclined to twenty five degrees, and slush it so that boarders could not keep their feet, but must slide into the water, they not having a pin or rope to hold by. The steam-engine would give a vessel of this description the means of playing

around the enemy, to take choice of position on her bow or quarter, and with little or no risk sink everything that came into our waters.

For sea service we must depend more on numbers, of which the calculations are in favour of my plan, —

A seventy-four will cost $600,000, and then the seventy-four of an enemy is equal to her in power. The enemy also have such fleets as will enable them to bring two to one; therefore the chances are against us. For $600,000 I can build seven vessels. Were they to attack a seventy-four, she could not dismast the whole of them; some one must get within the range of eight or ten feet of her, where one fire from any one of them would certainly destroy her. This changes the chances seven to one in our favour, and against the enemy, for the same capital expended.

This represents the seven vessels bearing down on

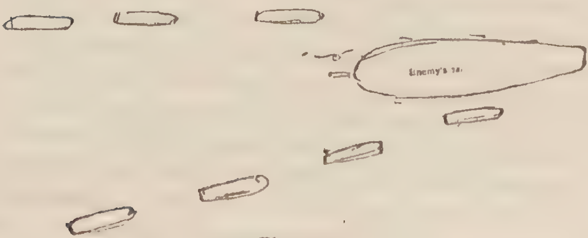

Fig. 10.

an enemy. Here it is obvious that she cannot bring her guns to bear on more than one or two of them;

if she lies to to fight, they must surround her; but if she sails better than any of them, and runs away, our object is gained, for then she can be driven off the ocean into port. As columbiads of 9-inch caliber are tremendous engines for close quarters, I could have two on pivots and circular carriages within my wooden walls, as thus, which being loaded with

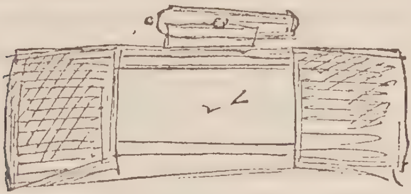

Fig. 11.

semi-shot and chains twenty feet long, would at two hundred yards distance, while bearing down, cut her rigging, and disable her before coming to close action. We are now engaged in a war for principles important to our independence and interest as an active and great commercial nation, and if we fail, generations to come must contend for it until they succeed. At all events, millions must be expended, which, if as successful as our present hope, will fall far short of the liberty of the seas. In expectation to discover in the concealed magazines of science some certain mode for destroying military navies, and thereby establishing a perfect liberty of the seas, I have laboured at intervals with much ardour for thirteen

years. I now submit to your reflections whether I have found it. My present impression, and Commodore Decatur's, is that I have. This is also the opinion of many friends. For you will consider, that if those vessels can destroy such as now exist, they cannot be used against each other without both parties going to the bottom; and such war cannot be made, — as duels would never be fought if both parties were obliged to sit on a cask of powder, and ignite it with a quick-match.

Two millions of dollars would build twenty such vessels; sixty men to each would be sufficient. Total, twelve hundred men. Such a fleet would clear our coast; and the probability is it would be the most powerful fleet in the world. One, however, should be built by Government, to establish principles on the public mind which are already proved in private. On the whole of this subject, after you have maturely reflected, it will give me great pleasure to have your opinions; and if it coincides with mine, your influence at Washington may be necessary to carry it into effect. I sincerely hope this new art may give many pleasing hours to your evening of life. As this wish is from the heart, it is better than the usual unmeaning compliments with which letters are concluded.

ROBERT FULTON.

SPECIFICATION.

I, Robert Fulton, give the following specification of my invention for injuring or destroying ships and vessels of war, by igniting gunpowder below a line horizontal to

the surface of the water, or so that the explosion which causes injury to the vessel attacked shall be under water. Therefore, instead of having the cannon and port-holes of a ship or vessel of war as usual, above the surface of the water, I place my cannon so low in the vessel that their port-holes will be below the surface of the water any number of inches or feet which may be required, from six inches to four, six, ten, or more feet; and thus, the cannon being fired with its muzzle under water, the bullets will pass through the water instead of through air, and through the sides of the enemy, from one to ten or more feet below the water-line, which, letting in the water in quantity according to the size of the holes and their depth under the surface, will sink the vessel attacked.

Drawing the First

represents the mechanism by which a cannon may be loaded inside of a ship, its muzzle be presented to hole in the side of the ship below the water-line, then be fired, its ball pass out through water, the cannon recoil into the ship, and the port-hole shut without letting in any inconvenient quantity of water. The gun may again be loaded and fired as before.

For this purpose a ring or flange is cast round the cannon, near its muzzle, which may be filled in with hemp like the packing of the piston of a steam-engine, or with leather, like the piston of a pump; a strong cylinder of brass or iron, or the most fit metal for the water in which it is to be used, is to be neat and smoothly bored, like the air-pump or cylinder of a

steam-engine, and of a size exact to receive the muzzle of the cannon, with its before-mentioned packing; hence, when the muzzle is pushed into the cylinder, it will be air and water tight, like the piston of a forcing-pump. The cylinder may be one, two, or more feet long, as the use may require; on its outer end a strong head and flange cast, which flange receives screw-bolts, to fasten it tight in the side of the vessel. In the centre of the said head there is a hole two inches in diameter greater than the caliber of the cannon to be used for the cylinder. The cannon being run home until its muzzle touches the head of the cylinder, as in the drawing, the cover to the hole is to be turned to one side, and the cannon fired, the ball and charge passing through the hole. On the recoil of the cannon, the sliding piece which covers the hole will descend and stop out the water. On this plan the cannon may be mounted on a carriage with wheels or not, as future experience may prove best, and always recoil, and be worked in a line direct to the cylinder which is to receive the muzzle. In my experience so far, when the cannon is loaded as usual, I put a kind of tompkin or stopper in the muzzle, with canvas and white lead to keep the water out of the gun. Thus I have found the gun to fire perfectly well without any risk or accident. Although this mode may be good in practice, I do not positively know that the water might not be admitted into the gun, up to a water-tight wad. The first plan will do; the latter may be proved in future practice. Cannon may be thus arranged under the water-line in such vessels of war as are usually built; but as the

whole battery comes below water, and may be several feet below, the vessel above the water-line may be made five, six, or more feet thick, of pine logs, or other wood, of hay or cotton or old rope or cabbage-tree, or any kind of material which will be bullet-proof. Thus all the men will be out of danger, as in the drawing.

Cannon may be placed in the bow of a vessel, near the keel as in drawing, or suspended over the bow or sides as in drawings, and be fired with water-proof locks, constructed for common or fulminating powder. Various other modes of practice may be devised; but the whole merit of this invention consists in having discovered and proved that cannon can be fired to greater advantage for the destruction or annoyance of an enemy, when so placed that the muzzle shall be under water, and the ball pass through water for the whole or greater part of the space it has to go till it strikes the enemy. The practice then will be with strong bullet-proof vessels to run alongside of an enemy within thirty, twenty, or ten feet, give her a broadside of one, two, three, four, or more heavy pieces from thirty-two to one-hundred pounders, from four to twelve or fifteen feet below the water-line, and retire. Of this whole system of firing cannon, carronades, columbiads, or ordnance of any kind *under water*, so as thus to attack an enemy to advantage, I claim to be the original inventor, and claiming it as my right, I have deemed it sufficient to give one mechanical and practicable combination, — being improvements previous to further experiments. But any attempt to fire any kind of ordnance under

water in attacks on vessels of war, or maritime combat, will be considered a violation of my right and purvey of my invention.

(Signed) ROBERT FULTON.

Fulton had been in America but a few weeks when he collected his papers and drawings and went to Washington, to urge upon the Government his plan for torpedo and submarine warfare. He secured a small appropriation, returned to New York, set up his apparatus on Governor's Island, and prepared to explain it to the representatives of the army and navy, and such others as were interested in the subject. He carried out a series of experimental demonstrations of the value of his inventions, in the course of which he blew up a vessel provided by the Government for the purpose, in the harbour of New York, and completely annihilated it, or, as Fulton himself said, "*decomposed*" it.

Descriptions of his inventions and of his experiments were, a little later, published by Fulton, in his "Torpedo War," a book addressed to the President of the United States and Members of Congress. The result was that Congress passed an act permitting the extension of these experiments, and for some years after this date (1810), in fact up to the time of his death, Fulton was engaged intermittently in the prosecution of his studies, and in experiments in this direction. A commission was appointed to witness and report on his work, and Government continued its interest in the subject to the end.

Reigart says that Chancellor Livingston, after a long examination of each particular subject which the experiments had suggested, expressed himself as follows: —

"Upon the whole, I view this application of powder as one of the most important military discoveries which some centuries have produced. It appears to me to be capable of effecting the absolute security of your ports against naval aggression, provided that, in conjunction with it, the usual means necessary to occupy the attention of the enemy are not neglected."

The reports were forwarded to the Secretary of the Navy by Mr. Fulton, with a letter from himself. His buoyant mind was never to be depressed. He gives his own views of the experiments, and writes with increased confidence in his ultimate success. He expresses himself satisfied with the report of the committee, and thinks their opinions were as favourable to the infant art as, under the circumstances, could have been expected. It is due to Mr. Fulton to give some extracts from this letter. He says: —

"It is proved and admitted, first, that the waterproof locks will ignite gunpowder under water; secondly, it is proved that seventy pounds of powder, exploded under the bottom of a vessel of two hundred tons, will blow her up; hence it is admitted, that if a sufficient quantity of powder — and which I believe need not be more than two hundred pounds — be ignited under the bottom of a first-rate man of war, it would instantly destroy her; thirdly, it is proved and admitted by all parties concerned in the

experiments, that a gun can be fired under water, and that a cable of any size can be cut by that means, at any required depth. With these immediately important principles proved and admitted, the question naturally occurs, whether there be, within the genius or inventive faculties of man, the means of placing a torpedo under a ship in defiance of her powers of resistance. He who says that there is not, and that consequently torpedoes never can be rendered useful, must of course believe that he has penetrated to the limits of man's inventive powers, and that he has contemplated all the combinations and arrangements which present or future ingenuity can devise to place a torpedo under a ship. I will do justice to the talents of Commodore Rodgers. The nets, booms, kentledge, and grapnels which he arranged around the 'Argus' made a formidable appearance against one torpedo boat and eight bad oarsmen. I was taken unawares. I had explained to the officers of the navy my means of attack; they did not inform me of their means of defence. The nets were put down to the ground; otherwise I should have sent the torpedoes under them. In this situation, the means I was provided with being imperfect, insignificant, and inadequate to the effect to be produced, I might be compared to what the inventor of gunpowder would have appeared, had he lived in the time of Julius Cæsar, and presented himself before the gates of Rome with a four-pounder, and had endeavoured to convince the Roman people that by means of such machines he could batter down their walls. They

would have told him that a few catapultas, casting arrows and stones upon his men, would cause them to retreat; that a shower of rain would destroy his ill-guarded powder; and the Roman centurions, who would have been unable to conceive the various modes in which gunpowder has since been used to destroy the then art of war, would very naturally conclude that it was an useless invention; while the manufacturers of catapultas, bows, arrows, and shields, would be the most vehement against further experiments. I had not one man instructed in the use of the machines, nor had I time to reflect on this mode of defending a vessel. I have now, however, had time; and I feel confident that I have discovered a means which will render nets to the ground, booms, kentledge, grapnel, oars with sword-blades, through the port-holes, and all such kinds of operations, totally useless."

The day after this most striking experiment, Mr. Fulton addressed a letter to the governor, and the mayor, and members of the corporation of New York, from which the following are extracts: —

"Yesterday my desire to satisfy public curiosity at the stated minute was as great as my never-ceasing anxiety to see our harbours and coast placed beyond the power of foreign insults, and I lament exceedingly that numbers were disappointed by the explosion not taking on the first attack, but it has given me much additional confidence in my engines.

"On taking the torpedoes out of the water, where they had been for two hours, I found the locks and

powder perfectly dry. I immediately discovered the cause of the failure, which I corrected by placing a piece of quick-match in the charge which the lock contained. Thus arranged, the fire was communicated to the seventy pounds of powder in the body of the torpedoes, an explosion took place, and the brig was decomposed.

"You have now seen the effect of the explosion of powder under the bottom of a vessel; and this, I believe, is the best and most simple mode of using it with the greatest effect in marine wars; for a right application of one torpedo will annihilate a ship, nor leave a man to relate the dreadful catastrophe. Thus, should a ship-of-the-line, containing five hundred men, contend with ten good row-boats, each with a torpedo and ten men, she would risk total annihilation, while the boats under the cover of the night, and quick movements, would risk only a few men out of a hundred.

"When two ships of equal force engage, it may be doubtful which will gain the victory. Frequently one hundred men are killed on each side, as many wounded, and the ships much injured; but even the vanquished vessels will admit of being repaired, and thus the number of ships-of-war is not diminished, but continue to increase and tyrannize over the rights of neutrals and peaceable nations.

"Having now clearly demonstrated the great effect of explosion under water, it is easy to conceive that by organization and practice the application of the torpedoes will, like every other art, progress in per-

fection. Little difficulties and errors will occur in the commencement, as has been the case in all new inventions; but where there is little expense, so little risk, and so much to be gained, it is worthy of consideration whether this system should not have a fair trial. Gunpowder, within the last three hundred years, has totally changed the art of war, and all my reflections have led me to believe that this application of it will in a few years put a stop to maritime wars, give that liberty of the seas which has been long and anxiously desired by every good man, and secure to America that liberty of commerce, tranquillity, and independence, which will enable her citizens to apply their mental and corporeal faculties to useful and humane pursuits, to the improvement of our country, and the happiness of the whole people."

Colden describes one of these schemes as almost the last work in which the active and ingenious mind of Mr. Fulton was engaged. This was a project for the modification of his submarine boat. "He had contrived a vessel which was to have a capacity, by means of an air-chamber like that which was in his 'Nautilus,' to be kept at a greater or less depth in the water, but so that her deck should not be submerged. That chamber communicated with the water, and was shaped like a diving bell; but it could at pleasure, by an air-pump, be exhausted of air, and then it would, of course, fill with water; or any requisite quantity of air could be forced into it, so as to expel the water from it entirely. The sides of the vessel were to be of the ordinary thickness, but her

deck was to be stout and plated with iron, so as to render it ball-proof, which would not require so much strength as might be at first imagined, because, as no shot could strike it from a vessel but at a very great angle, the ball would ricochet on a slight resistance from a hard substance. She was to be of a size capable of sheltering a hundred men under her deck, and was to be moved by a wheel placed in another air-chamber near the stern, so that when the vessel was to be propelled only a part of the under paddles should be in water; at least, the upper half of the wheel, or more, moving in air. The wheel was to be turned by a crank attached to a shaft, that should penetrate the stern to the air-chamber through a stuffing-box, and run along the middle of the boat until it approaches her bows. Through this shaft rungs were to be passed, of which the crew were to take hold as they were seated upon each side of it on benches. By merely pushing the shaft backward and forward the water-wheel would be turned, and the boat be propelled with a velocity equal to the force of a hundred men. By means of the air-chamber, she was to be kept, when not in hostile action, upon the surface, as common boats are; but when in reach of an enemy she was to sink, so that nothing but her deck would be exposed to his view or to his fire. Her motion when in this situation would be perfectly silent, and therefore he called this contrivance a mute. His design was that she should approach an enemy, which he supposed she might do in fogs or in the night, without being heard or discovered, and

do execution by means of his torpedoes or submarine guns. He presented a model of this vessel to the Government, by which it was approved; and under the authority of the Executive he commenced building one in this port; but before the hull was entirely finished, his country had to lament his death, and the mechanics he had employed were incapable of proceeding without him."[1]

[1] Colden's Life of Fulton, p. 233.

VI.

FULTON'S EXPERIMENTS WITH STEAM. — THE "CLERMONT."

In the opening chapter of this book we have traced the progress of invention in the applications of steam, especially in the direction of its use in navigation, and have seen how the minds of all great philosophers and mechanics were turning toward the solution of this now visible and almost imperative problem. It has been seen that, before Fulton's experiments were begun, a number of inventors on both sides of the Atlantic were engaged in the work, and that some progress had been made; so much, in fact, that the outcome could hardly be doubted. Papin had, early in the eighteenth century, as we have seen, actually built a steamboat; Jonathan Hulls, in 1737, secured British patents on another form; William Henry had put his little boat on the Conastoga River in 1763; the Comte d'Auxiron had launched a steamer on French waters in 1774; ten years later Oliver Evans and James Rumsey came forward with their peculiar systems of propulsion; John Fitch appeared at about the same date, 1785, building a number of boats, and succeeding, apparently, in attaining seven miles an hour in his boat of 1790, and making a total of several thousands of miles in its regular work as a

passenger boat between Philadelphia and Bordentown, Pennsylvania. Fitch's screw-boat, built forty-five years after Bernouilli had written his prize-essay suggesting the use of the "spiral oar," — as James Watt called it when proposing it, independently, about 1784, — was sufficiently satisfactory, as proving the practicability of the device, when tried on Collect Pond, in New York City, in 1796. His contemporary in France, the Marquis de Jouffroy, had built two steamers on the Rhone, in 1781–1783; and in Scotland, Miller, Taylor, and Symmington had almost succeeded, their efforts finally resulting in a real success, in 1801, when the Charlotte Dundas was built as a "stern-wheeler" on the Forth and Clyde Canal. Samuel Morey had put a little steamer on the Connecticut in 1790, and many other mechanics and inventors were busy in the same work by the time Fulton had reached that problem, among whom were two of Fulton's own later friends — Livingston and Roosevelt, — and his most enterprising rival, John Stevens, the four working together to build a boat on the Passaic River in 1798. Fulton had, as early as 1798, proposed plans for steam-vessels to both the United States and British governments.[1] He had been too busy with his other schemes to pay much attention to this until satisfied that he was to expect nothing from the former.

Fulton's experiments began while he was in Paris, and may have been stimulated by his acquaintance with Chancellor Livingston, who held the monopoly,

[1] History of the Steam-Engine, R. H. Thurston; Life of Fulton, Colden.

offered by the legislature of the State of New York, for the navigation of the Hudson River, to be accorded to the beneficiary when he should make a successful voyage by steam. Livingston was now ambassador of the United States to the Court of France, and had become interested in the young artist-engineer, meeting him, presumably, at the house of his friend Barlow. It was determined to try the experiment at once, and on the Seine.

The giving of monopolies in the form here alluded to was, in those days, before the introduction of the modern systems of patent-law, a very common method of securing to inventors their full reward. John Fitch had been given a monopoly of this kind by the United States government for a period of fourteen years from March 19, 1787; which monopoly was later (1798) repealed by Congress; this repeal being, in turn, denied by the courts, March 13, 1798, and subsequently continued to June 1, 1819, meantime being transferred to Nicholas J. Roosevelt. The State Act in favour of Livingston was passed to take effect April 5, 1803, and was repealed as unconstitutional, and conflicting with the jurisdiction of the United States, June 17, 1817. The whole system went out of use at the latter date, as it was found to be dangerous and troublesome, and on the whole far inferior to that admirable patent-system which succeeded it, and which has done so much to promote the marvellous prosperity of the country since the first quarter of the nineteenth century.

Fulton went to Plombières in the spring of 1802,

and there made his drawings and completed his plans for the construction of his first steamboat. Many attempts had been made, as we have seen, and many inventors were at work contemporaneously with him. Every modern device, — the jet-system, the "chaplet" of buckets on an endless chain or rope, the paddle-wheel, and even the screw-propeller — had been already proposed, and all were familiar to the well-read man of science of the day. Indeed, as Mr. Benjamin H. Latrobe, a distinguished engineer of the time, wrote in a paper presented May 20, 1803, to the Philadelphia Society, "A sort of mania began to prevail" for propelling boats by means of steam-engines. Fulton was one of those taking this mania most seriously. He made a number of models which worked successfully, and justified the proprietors of the new arrangement in building on a larger scale. A model of the proposed steamboat was made during the year 1802, and was presented to the committee of the French legislature with the note of which a copy is given below. This latter document was discovered in the following manner, as described by "La Nature" in 1880: —

Jacques de Vaucanson, the French mechanician, was born in Grenoble, Feb. 24, 1709, and died in Paris, Nov. 21, 1782. He studied mechanics and anatomy for several years. The statue of the Flute-Player in the gardens of the Tuileries first suggested to him the project of making an automaton player, and he acquired great celebrity by works of this class. Cardinal Fleury appointed him inspector

of silk manufactures; and in consequence of his improvements in machinery he was attacked by the workmen of Lyons. He retaliated by constructing an automaton ass weaving flowered silks. He bequeathed his collection to the queen, who gave it to the Academie des Sciences. It was afterward scattered, in consequence of a contest with the mercantile authorities for the possession of the manufacturing machinery. His portfolio, containing drawings and documents of great historical value, is now in possession of the Conservatoire des Arts et Métiers, at Paris. One of the most valuable things in the collection is Fulton's design for his first steamboat, accompanied by an autograph letter:—

PARIS, 4 Pluviose, Year 11 (1803).

ROBERT FULTON TO CITIZENS MOLAR, BANDELL, AND MONTGOLFIER.

FRIENDS OF THE ARTS,—I send you herewith drawings sketched from a machine that I have constructed, and with which I purpose soon to make experiments in causing boats to move on rivers by the aid of fire-pumps (*pompes-à-feu*). My first aim, in occupying myself with this idea, was to put it in practice on the long rivers of America, where there are no tow-paths, and where these would scarcely be practicable, and where, consequently, the expense of navigation by steam would be placed in comparison with that of manual labour, and not with that of horse-power, as in France.

In these drawings you will find nothing new, since

they are only [those of] water-wheels, — a method which has been often tried, and always abandoned because it was believed that a purchase could not be thereby obtained in the water. But after the experiments that I have made, I am convinced that the fault has not been in the wheel, but in ignorance of proportions, velocities, powers, and probably mechanical combinations. . . . Citizens, when my experiments are ready, I shall have the pleasure of inviting you to witness them; and if they succeed, I reserve to myself the privilege of either making a present of my labours to the Republic, or deriving therefrom the advantages which the law authorizes. At present, I place these notes in your hands, so that if a like project should reach you before my experiments are finished, it may not have preference over my own.

Respectfully,

ROBERT FULTON.

The drawings alluded to included that here shown, which has been reduced from the original, which is still safely preserved in Paris. As will be seen later, the general character of the vessel is that subsequently made so successful in America, and the form of the engine is precisely that of the later "Clermont."

Fulton seems to have been considered, even at this early day, an authority on the subject of steam-navigation. Admiral Preble, in his History of Steam Navigation, (p. 35) quotes the following letter to a friend, written after his work on his own scheme for that season was over: —

PARIS, the 20th of Sept., 1802.

TO MR. FULNER SKIPWITH.

SIR, — The expense of a patent in France is 300 livres for three years, 800 ditto for ten years, and 1,500 ditto for fifteen years. There can be no difficulty in obtaining a patent for the mode of propelling a boat which you have shown me; but if the author of the model wishes to be assured of the merits of his

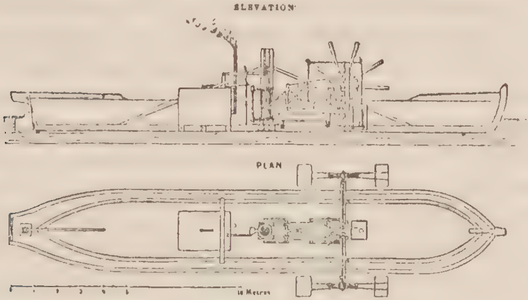

Fig. 7. — Fulton's First Steamboat.

invention before he goes to the expense of a patent, I advise him to make the model of a boat in which he can place a clock-spring, which will give about eight revolutions. He can then combine the movements so as to try oars, paddles, and the leaves which he proposes. If he finds that the leaves drive the boat a greater distance in the same time than either oars or paddles, they consequently are a better application of power. About eight years ago, the Earl of Stanhope tried an experiment on similar leaves, wheels, oars, and paddles, and flyers similar to those

of a smoke-jack, and found oars to be the best. The velocity with which a boat moves is in proportion as the sum of the surfaces of the oars, paddles, leaves, or other machine is to the bow of the boat presented to the water, and in proportion to the power with which such machinery is put in motion. Hence, if the use of the surfaces of the oars is equal to the sum of the surfaces of the leaves, and they pass through similar curves in the same time, the effect must be the same. But oars have their advantage; they return through air to make a second stroke, and hence create very little resistance; whereas the leaves return through water, and add considerably to the resistance, which resistance is increased as the velocity of the boat is augmented. No kind of machinery can create power. All that can be done is to apply the manual or other power to the best advantage. If the author of the model is fond of mechanics, he will be much amused, and not lose his time, by trying the experiments in the manner I propose; and this perhaps is the most prudent measure, before a patent is taken. I am, sir, with much respect,

Yours, ROBERT FULTON.

At this time the inventors had taken up the problem, as we have seen, and several had been, during the preceding twenty years, working with more or less success to secure what every statesman of the period saw would be ultimately a step toward the attainment of that great aim of Fulton, the commercial freedom of the seas. As early as 1794, Lord Stanhope

addressed a letter to Wilberforce on the question of peace or war, likely, he thought to be brought under discussion on the meeting of Parliament. In this letter he speculates on the possible resources of France, and hints that England is not invulnerable. He says: —

"This country [Great Britain] is vulnerable in so many ways, the picture is horrid. By my letter I will say nothing on that subject. One instance, I will, however, state, because it is information you cannot, as yet, receive from any other quarter; though in two or three months from the date of this letter the fact will be fully established, and you may then hear it from others. The thing I allude to is of peculiar importance. The fact is this: I know (and in a few weeks shall prove) that ships of any size, and for certain reasons the larger the better, may be navigated in any narrow or other sea, without sails (though occasionally with), but so as to go without wind, and even directly against both wind and waves. The consequences I draw are as follows: First, that all the principal reasons against the French having the ports of Ostend, etc., cease, inasmuch as a French fleet composed of ships of the above-mentioned description, would come out at all times from Cherbourg, Dunkirk, etc., as well as from Ostend, etc., and appear in the same seas. The water, even at Dunkirk, will be amply deep enough for the purposes of having them there. The French having Ostend, ought not, therefore, under this new revolution in naval affairs, — for it would be a complete revolution, — to be a bar to peace.

Under the old nautical system, naval men might have reasoned differently on that subject. But the most important consequence which I draw from this stupendous fact mentioned at the top of this page is this; namely, that *it will shortly render all the existing navies of the world (I mean military navies) no better than lumber.* For what can ships do that are dependent upon wind and weather against fleets wholly independent of either? Therefore the boasted superiority of the English navy is no more! We must have a new one. The French and other nations will, for the same reasons, have their new ones."[1]

The apprehension of Stanhope was the hope of Fulton; but neither the hope nor the apprehension has as yet been verified. The introduction of steam-navigation became a success; but that success came so slowly as to permit all nations to avail themselves of it, and none sooner or more completely than the two most active in the production of this revolution, — Great Britain and the United States. The British navy became a steam-navy, and the other nations of the world followed her lead; so that the strife of the century, at sea, has been a struggle between, and for, steam-fleets. In this direction, the introduction of steam has resulted in the increased expenditure of money on fleets in such enormous amounts as to tax the people to the very limit of their endurance; while the relative order in naval power of the greater nations has been comparatively little altered.

[1] Preble, p. 28.

With the encouragement of Chancellor Livingston, who urged upon Fulton the importance of the introduction of steam-navigation into their native country, the latter continued his experimental work. Their boat was finished and set afloat on the Seine in 1803, in the early spring. Its proportions had been deter-

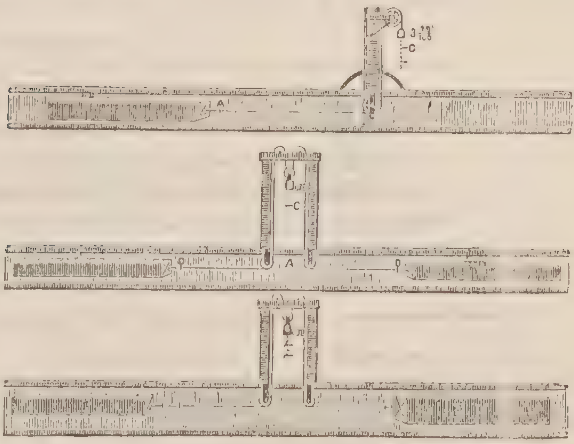

Fig. 8. — Fulton's Experiments.

mined by careful computation from the results of no less careful experiment on the resistance of fluids and the power required for propelling vessels; and its speed was, therefore, more nearly in accord with the expectations and promises of the inventor than was the usual experience in those days.

The Author has examined a collection of Fulton's sketches of these plans, including chaplet, side-

wheel and stern-wheel boats, driven by various forms of steam-engine, some working direct, and some geared to the paddle-wheel shaft. Figure 8 is engraved from these sheets. It represents the method adopted by Fulton to determine the resistance of various forms and proportions of bodies towed through water. Figure 9 is "A Table of the resistance of

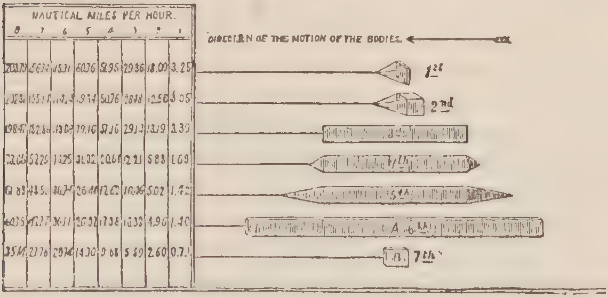

Fig. 9. — Fulton's Table of Resistances.

bodies moved through water, taken from experiments made in England by a society for improving Naval architecture, between the years 1793 and 1798." This is from a certified copy of "The Original Drawing on file in the Office of the Clerk of the New York District, making a part of the Demonstration of the patent granted to Robert Fulton, Esqr., on the 11th day of February, 1809. Dated this 3rd March, 1814."

Guided by these experiments and calculations, therefore, Fulton directed the construction of his vessel. The hull was sixty-six feet long, of eight feet

beam, and of light draught. But unfortunately the hull was too weak for its machinery, and it broke in two and sank to the bottom of the Seine. Fulton at once set about repairing damages. He was compelled to direct the rebuilding of the hull, but the machinery was but slightly injured. In June, 1803, the reconstruction was complete, and the vessel was set afloat in July.

August 9, 1803, this boat was cast loose in presence of an immense concourse of spectators, including a committee of the National Academy, consisting of Bougainville, Bossuet, Carnot, and Périer. The boat moved but slowly, making only between three and four miles an hour against the current, the speed through the water being about $4\frac{1}{2}$ miles; but this was, all things considered, a great success.

The experiment attracted little attention, notwithstanding the fact that its success had been witnessed by the committee of the Academy and by officers on Napoleon's staff. The boat remained a long time on the Seine, near the palace. The water-tube boiler of this vessel (Figure 10) is still preserved at the Conservatoire des Arts et Métiers at Paris, where it is known as Barlow's boiler. Barlow patented it in France as early as 1793, as a steamboat-boiler, and states that the object of his construction was to obtain the greatest possible extent of heating-surface.

Fulton endeavoured to secure the pecuniary aid and the countenance of the First Consul, but in vain.

Livingston wrote home, describing the trial and its

results, and procured the passage of an Act by the legislature of the State of New York, extending, nominally to Fulton, a monopoly granted the former in 1798 for the term of twenty years from April 5, 1803, — the date of the new law, — and extending the time allowed for proving the practicability of driving a boat four miles an hour by steam to two years from the same date. A later act further extended the time to April, 1807.

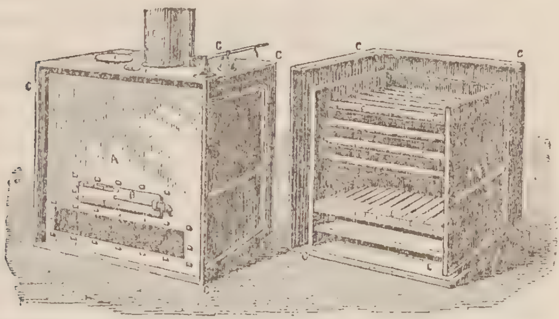

Fig. 10. — Barlow's Water-Tube Boiler, 1793.

In May, 1804, Fulton went to England, giving up all hope of success in France with either his steamboats or his torpedoes, and the chapter of his work in Europe practically ends here. He had already written to Boulton & Watt, ordering an engine to be built from plans which he furnished them; but he had not informed them of the purpose to which it was to be applied. This engine [1] was to have a steam-

[1] Thurston's History of the Steam-Engine, p. 256.

cylinder two feet in diameter and of four feet stroke. Its form and proportions were substantially those of the boat-engine of 1803.

Meantime, the opening of the century had been distinguished by the beginning of work in the same direction by the most active and energetic among Fulton's later rivals. This was Col. John Stevens of Hoboken, who, assisted by his son, Robert L. Stevens, was earnestly engaged in the attempt to seize the prize now so evidently almost within the grasp. This younger Stevens was he of whom the great naval architect and engineer, John Scott Russell, afterward remarked: "He is probably the man to whom, of all others, America owes the greatest share of its present highly improved steam-navigation."[1] The father and son worked together for years after Fulton had demonstrated the possibility of reaching the desired end, in the improvement of the hulls and machinery of the river steamboat, until in their hands, and especially in those of the son, the now familiar system of construction in all its essentials was developed. The elder Stevens, as early as 1789, evidently had seen what was in prospect, and had petitioned the legislature of the State of New York for a grant similar to that actually accorded Livingston, later; and he had certainly, at that time, formed plans for the application of steam-power to navigation. The records show that he was at work on construction as early, at least, as 1791. The following is a brief state-

[1] Steam and Steam-Navigation, J. S. Russell, Edinburgh, 1841.

ment of his work, mainly as elsewhere given by the Author.[1]

In 1804 Stevens completed a steamboat sixty-eight feet long and of fourteen feet beam. Its boiler (Figure 11) was of the water-tubular variety. It con-

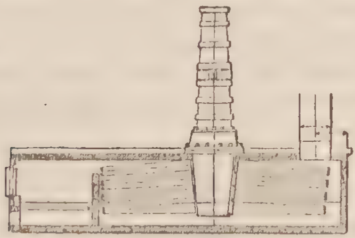

Fig. 11. — Section of Steam-Boiler, 1804.

tained one hundred tubes, two inches in diameter and eighteen inches long, fastened at one end to a central water-leg and steam-drum. The flames from the furnace passed among the tubes, the water being inside.

Fig. 12. — Engine, Boiler, and Screw-Propellers, used by Stevens, 1804.

The engine (Figure 12) was *direct-acting high-pressure* condensing, having a 10-inch cylinder, two feet stroke

[1] History of the Growth of the Steam-Engine, p. 264.

of piston, and driving a well-shaped *screw*, with four blades.

This machinery, — the high-pressure condensing engine, with rotating valves, and *twin* screw-propellers, — as rebuilt in 1805, is still preserved. The hub and blade of a single screw, also used with the same machinery in 1804, is likewise extant.

Stevens's eldest son, John Cox Stevens, was in Great Britain in the year 1805, and while there patented a modification of this sectional boiler. In his

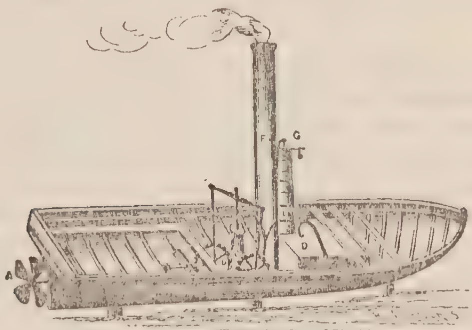

Fig. 13. — Stevens's Screw-Steamer, 1804.

specification he says that he describes this invention as it was made known to him by his father, and adds:

"From a series of experiments made in France, in 1790, by M. Belamour, under the auspices of the Royal Academy of Sciences, it has been found that, within a certain range, the elasticity of steam is nearly doubled by every addition of temperature equal to 30° of Fahrenheit's thermometer. These experi-

ments were carried no higher than 280°, at which temperature the elasticity of steam was found equal to about four times the pressure of the atmosphere. By experiments which have lately been made by myself, the elasticity of steam at the temperature of boiling oil, which has been estimated at about 600°, was found to equal forty times the pressure of the atmosphere.

"To the discovery of this principle or law, which obtains when water assumes a state of vapour, I certainly can lay no claim; but to the application of it, upon certain principles, to the improvement of the steam-engine, I do claim exclusive right.

"It is obvious that, to derive advantage from an application of this principle, it is absolutely necessary that the vessel or vessels for generating steam should have strength sufficient to withstand the great pressure from an increase of elasticity in the steam; but this pressure is increased or diminished in proportion to the capacity of the containing vessel. The principle, then, of this invention consists in forming a boiler by means of a system, or combination, of a number of small vessels, instead of using, as in the usual mode, one large one, the relative strength of the materials of which these vessels are composed increasing in proportion to the diminution of capacity. It will readily occur that there are an infinite variety of possible modes of effecting such combinations; but, from the nature of the case, there are certain limits beyond which it becomes impracticable to carry on improvement. In the boiler I am about to describe, I apprehend that the improvement is carried to the

utmost extent of which the principle is capable. Suppose a plate of brass of one foot square, in which a number of holes are perforated, into each of which holes is fixed one end of a copper tube, of about an inch in diameter and two feet long, and the other ends of these tubes inserted in like manner into a similar piece of brass; the tubes, to insure their tightness, to be cast in the plates; these plates are to be inclosed at each end of the pipes by a strong cap of cast-iron or brass, so as to leave a space of an inch or two between the plates or ends of the pipes and the cast-iron cap at each end; the caps at each end are to be fastened by screw-bolts passing through them into the plates; the necessary supply of water is to be injected by means of a forcing-pump into the cap at one end, and through a tube inserted into the cap at the other end the steam is to be conveyed to the cylinder of the steam-engine; the whole is then to be encircled in brick-work or masonry in the usual manner, placed either horizontally or perpendicularly, at option.

"I conceive that the boiler above described embraces the most eligible mode of applying the principle before mentioned, and that it is unnecessary to give descriptions of the variations in form and construction that may be adopted, especially as these forms may be diversified in many different modes."

Boilers of the character of those described in this specification were used on a locomotive built by John Stevens, in 1824–1825.

The use of a high-pressure sectional boiler seventy

years ago is more remarkable than the adoption of the screw-propeller thirty years before the screw came into general use.

Colonel Stevens designed a form of iron-clad in the year 1812, since reproduced by the late John Elder, of Glasgow, Scotland. It consisted of a saucer-shaped hull, plated with iron of ample thickness to resist the shot fired from the heaviest ordnance then known. This vessel was to be secured to a swivel, and anchored in the channel to be defended

Fig. 14.—Stevens's Twin-Screw Steamer, 1805.

A set of screw-propellers, driven by steam-engines, and situated beneath the vessel, were arranged to permit the vessel to be rapidly revolved about its centre, working thus on the principle of the "turret" of Timby and Ericsson. As each gun came into line it was discharged, and then reloaded before coming around again. This, the first iron-clad ever designed, has recently been again brought out and introduced into the Russian navy, and called the "Popoffska."

Stevens next built a boat which he named the "Phœnix," and made the first trial in 1807, just too

late to anticipate Fulton. This boat was driven by paddle-wheels.

Stevens, being shut out of the rivers of the State of New York by the monopoly held by Fulton and Livingston, ran the "Phœnix" for a time between New York Bay and New Brunswick, and on the Delaware.

At that time no canal existed, and in June, 1808, Robert L. Stevens started to make the passage by sea. Although meeting a gale of wind, he arrived at Philadelphia safely, having been the first to make a sea voyage by steam-power.

From this time forward the Stevenses continued to construct steam-vessels, and, later, built the most successful steamboats on the Hudson River.

Before recurring to the work of Fulton, a few more paragraphs may be devoted to Stevens.[1]

Col. John Stevens, of Hoboken, was the greatest professional engineer and naval architect living at the beginning of the present century. Without having made any improvement in the steam-engine, like that which gave Watt his fame; without being the first to propose navigation by steam, or steam-transportation on land, he exhibited a better knowledge of engineering than any man of his time, and entertained and urged more advanced opinions, and more statesman-like views, in relation to the economical importance of the improvement of the steam-engine, both on land and water, than seem to have been attributable to any other leading engineer of that time, not excepting Robert Fulton.

[1] See a paper by the Author, "The Messrs. Stevens, as Engineers," etc.; Journal of the Franklin Institute, Oct., 1874.

Dr. Charles King, then the distinguished President of the Columbia College, thus refers to the work of this great man.[1]

"Mr. Stevens's attention was first turned, or rather the bent of his genius was developed and directed toward mechanics and mechanical philosophy, by the accident of seeing in 1787 the early and, as now may be said, imperfect steamboat of John Fitch navigating the Delaware River. He was driving in his phaeton on the banks of the river when the mysterious craft, without sails or oars, passed by. Mr. Stevens's interest was excited; he followed the boat to its landing, familiarized himself with the design and the details of this new and curious combination, and from that hour became a thoroughly excited and unwearied experimenter in the application of steam to locomotion on the water, and subsequently on the land.

"Having been brought by close family connection into intimacy with Robert R. Livingston (the Chancellor of this State, who married the sister of Colonel Stevens), he induced Mr. L. to join him in these investigations; and they were persevered in at great cost, and with little immediate success, till Chancellor Livingston, in 1801–1802, was sent as minister to France.

"So much, however, was the Chancellor encouraged by the experiments then made, that as early as 1798 he obtained from the legislature of New York an exclusive grant for the use of steam on the waters of New York. This, however, became forfeit by

[1] Lecture on the Progress of the City of New York, 1843.

the failure to avail within the limited time of its privileges.

"But previously to the Act of '98, the legislature of New York had, as early as 1787, granted to James Rumsey and to John Fitch the exclusive right to navigate the waters of the State with steam-propelled vessels; and on the 9th of January, 1789, John Stevens petitioned the legislature for a like grant, — nothing having resulted from the preceding ones. Mr. Stevens in his petition says that 'to the best of his knowledge and belief his scheme is altogether new, and does not interfere with the inventions of either of the other gentlemen who have applied to your honourable body for an exclusive right of navigating by means of steam.' The petitioner adds that he 'had made an exact draught of the different parts of his machine, which, with an explanation thereof, he is ready to exhibit.' The prayer of the petition was unsuccessful; but these draughts should be among the papers of the late Colonel Stevens, and at this day would be curious.

"Mr. Stevens, meanwhile, never renounced his experiments, nor despaired of success; and in 1804 he actually constructed a *propeller* (a small open boat, worked by steam), with such decided success that he was encouraged to go on and build the 'Phœnix' steamboat, on his own plan and model, and had her ready almost contemporaneously with, but a little after, the first steamboat of Fulton, the 'Clermont.' The success of the 'Clermont' entitled Mr. Fulton and Chancellor Livingston, who was co-operating with

Fulton, to the benefit of the law, which had been revived by the State of New York, granted a monopoly of the waters of the State, and thus Mr. Stevens's steamboat was excluded from those waters. On the Delaware, however, and on the Connecticut, he placed boats; and his eminent son, Robert L. Stevens, having embraced his father's views, was now at work with him to improve the known, and invent new resources for accelerated steam conveyance."

While Fulton was still abroad, John Fitch and Oliver Evans were pursuing a similar course of experiment, as were his contemporaries on the other side the Atlantic, and with more success. Fitch had made a number of fairly successful ventures, and had shown beyond question that the project of applying steam to ship-propulsion was a promising one; and he had only failed through lack of financial backing, and inability to appreciate the amount of power that must be employed to give his boats any considerable speed. Evans had made his "Oruktor Amphibolis," — a flat-bottomed vessel which he built at his works in Philadelphia, and impelled by its own engines, on wheels, to the bank of the Schuylkill, and then afloat, down the stream to its berth, by paddle-wheels driven by the same engines. Other inventors were working on both sides the ocean with apparently good reason to hope for success, and the times evidently were ripe for the man who should best combine all the requirements in a single experiment. The man to do this was Fulton.

He had made his own preliminary trials on the

Seine, and had there learned how to proceed to make a better steamer later; he had undoubtedly kept himself informed of what was being done by his rivals in Great Britain, as in France and the United States, as well as the imperfect facilities for communication of the beginning of the nineteenth century permitted; he had the natural talent of the inventor, the skill and training of the engineer, and was now backed by men of capital and sagacity, who had also that essential of final success, political power, and influence.

Fulton's experiments on the Seine so far encouraged him that, with the approval of Livingston, he immediately wrote to the firm of Boulton & Watt, in England, the builders of the engines of James Watt, then the junior member of the firm, and ordered an engine of which he gave them the dimensions and design, but which he did not inform them was to be used in steam-navigation. This engine was to be at once built and shipped to the United States, whither Fulton had decided to at once return. He himself went to England before returning to the United States, and, it is presumed, there saw the builders of his engine, and instructed them as to the details of its construction for adaptation to his purposes. It was very slowly constructed, however; and it was not until about the time of his own arrival at New York that it was received and made ready for its work. The boat was finally built and fitted with these engines, and at the expense of Fulton himself, who could find no one at the time ready to assume a portion of the, to him, somewhat costly outfit. Living-

ston seems to have remained behind, and to have left the whole burden to be borne by Fulton.

Immediately on his arrival, in the winter of 1806–7, Fulton started on his boat, selecting Charles Brown as the builder, a well-known ship-builder of that time, and the builder of many of Fulton's later steam-vessels. The hull of this steamer, which was the first to establish a regular route and regular transportation of passengers and merchandise in America, — Fulton's first boat in his native country, — was 133 feet long, 18 feet beam, and 7 feet depth of hold. The engine was of 24 inches diameter of cylinder, 4 feet stroke of piston; and its boiler was 20 feet long, 7 feet high, and 8 feet wide. The tonnage was computed at 160. After its first season, its operation having satisfied all concerned of the promise of the venture, its hull was lengthened to 140 feet, and widened to 16½ feet, thus being completely rebuilt; while its engines were altered in a number of details, Fulton furnishing the drawings for the alterations. Two more boats, the "Raritan" and the "Car of Neptune" were added to form the fleet of 1807, and steam-navigation was at last fairly begun in America, some years in advance of its establishment in Europe. The Legislature were so much impressed with this result that they promptly extended the monopoly previously given Fulton and Livingston, adding five years for every boat to be built and set in operation, up to a maximum not to exceed a total of thirty years.

The "Clermont," as Fulton called this first boat, was begun in the winter of 1806–7, and launched in

sails. The whole has therefore been performed by the power of the steam-engine.

I am, sir, your obedient servant,

ROBERT FULTON.

Fulton gives the following account of the same voyage in a letter to his friend, Mr. Barlow: —

"My steamboat voyage to Albany and back has turned out rather more favourably than I had calculated. The distance from New York to Albany is one hundred and fifty miles. I ran it up in thirty-two hours, and down in thirty. I had a light breeze against me the whole way, both going and coming, and the voyage has been performed wholly by the power of the steam-engine. I overtook many sloops and schooners beating to windward, and parted with them as if they had been at anchor.

"The power of propelling boats by steam is now fully proved. The morning I left New York, there were not perhaps thirty persons in the city who believed that the boat would ever move one mile an hour, or be of the least utility; and while we were putting off from the wharf, which was crowded with spectators, I heard a number of sarcastic remarks. This is the way in which ignorant men compliment what they call philosophers and projectors.

"Having employed much time, money, and zeal in accomplishing this work, it gives me, as it will you, great pleasure to see it answer my expectations. It will give a cheap and quick conveyance to the merchandise on the Mississippi, Missouri, and other great rivers, which are now laying open their treasures to

the enterprise of our countrymen; and, although the prospect of personal emolument has been some inducement to me, yet I feel infinitely more pleasure in reflecting on the immense advantage my country will derive from the invention,"[1] etc.

Professor Renwick, describing the "Clermont" of 1807 as she appeared on her first trip, says: "She was very unlike any of her successors, and very dissimilar from the shape in which she appeared a few months afterward. With a model resembling a Long Island skiff, she was decked for a short distance at stem and stern. The engine was open to view, and from the engine aft a house like that of a canal-boat was raised to cover the boiler and the apartment for the officers. There were no wheel-guards. The rudder was of the shape used in sailing-vessels, and moved by a tiller. The boiler was of the form then used in Watt's engines, and was set in masonry. The condenser was of the size used habitually in land engines, and stood, as was the practice in them, in a large cold-water cistern. The weight of the masonry and the great capacity of the cold-water cistern diminished very materially the buoyancy of the vessel. The rudder had so little power that she could hardly be managed. The skippers of the river craft, who at once saw that their business was doomed, took advantage of the unwieldiness of the vessel to run foul of her as [illegible] they thought they had the law on their side. Thus, in several instances, the steamer reached one or the other termini of the route with but a single wheel."

[1] Reigart, p. 173.

The "American Citizen" of August 17, 1807, says: —

"Mr. Fulton's ingenious steamboat, invented with a view to the navigation of the Mississippi, from New Orleans upward, sails to-day from the North River, near State's Prison, to Albany. The velocity of the steamboat is calculated at four miles an hour. It is said it will make a progress of two against the current

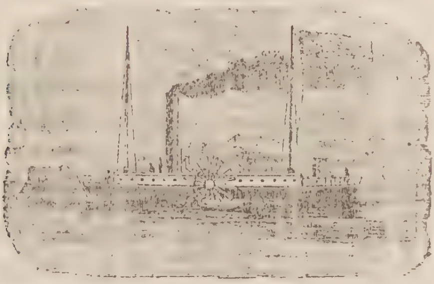

Fig. 15. — The "Clermont," 1807.

of the Mississippi, and if so it will certainly be a very valuable acquisition to the commerce of Western States."

What would this sanguine editor have thought, had he been assured that the "Clermont" was the pioneer of a fleet that should include steamships of ten thousand tons, or even — as the "Great Eastern," — of thirty thousand tons displacement; ships that should make a speed of twenty miles an hour at sea; small torpedo boats carrying out the idea of Fulton, and pursuing their enemy with their destructive little

weapons at speeds approaching thirty miles an hour; and river boats passing over the very route chosen for Fulton's first trial-trip at the speed of twenty-seven miles an hour, and at their "slow speeds," running from New York to Albany in ten hours or less? What would he have thought, had he dreamed of steaming from New York to Newport, to Fall River, or to Providence in ten to twelve hours? Of going from St. Louis to New Orleans in four days? Of crossing the Atlantic in six?

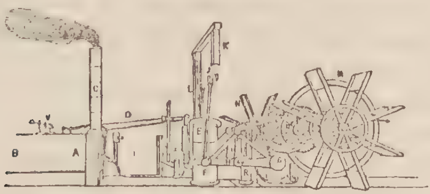

Fig. 16.—Engine of the "Clermont," 1808.

The engine of the "Clermont" (Figure 16), as already seen, was similar to that of Fulton's French boat, and of rather peculiar construction, the piston, E, being coupled to the crank-shaft, O, by a bell-crank, $I\ H\ P$, and a connecting-rod, $P\ Q$, the paddle-wheel shaft, $M\ N$, being separate from the crank-shaft, and connected with the latter by gearing, $O\ O$. The paddle-wheels had buckets four feet long, with a dip of two feet.

The voyage of the "Clermont" to Albany was attended by some ludicrous incidents. Mr. Colden says that she was described "as a monster, moving

on the waters, defying wind and tide, and breathing flames and smoke."

This boat used dry pine wood for fuel, and the flames rose to a considerable distance above the smoke-pipe; and mingled smoke and sparks rose high in the air. "This uncommon light first attracted the attention of the crews of other vessels. Notwithstanding the wind and tide were averse to its approach, they saw with astonishment that it was rapidly coming toward them; and when it came so near that the noise of the machinery and paddles was heard, the crews (if what was said in the newspapers of the time be true) in some instances shrank beneath their decks from the terrific sight, and left their vessels to go on shore; while others prostrated themselves, and besought Providence to protect them from the approach of the horrible monster which was marching on the tides, and lighting its path by the fires which it vomited."

Fulton used several of the now familiar features of the American river boat, and subsequently introduced others.

The success of the "Clermont" on the trial-trip was such that Fulton soon after advertised the vessel as a regular passenger boat between New York and Albany.

A newspaper-slip in the scrap-book of the Author has the following: —

"The traveller of to-day, as he goes on board the great steamboats 'St. John' or 'Drew,' can scarcely imagine the difference between such floating palaces

and the wee-bit punts on which our fathers were wafted sixty years ago. We may, however, get some idea of the sort of thing then in use by a perusal of the steamboat announcements of that time two of which are as follows: —

"'September 2, 1807.

"'The North River Steamboat will leave Pauler's Hook Ferry [now Jersey City] on Friday, the 4th of September, at 9 in the morning, and arrive at Albany on Saturday, at 9 in the afternoon. Provisions, good berths, and accommodations are provided.

"'The charge to each passenger is as follows:

"'To Newburg . .	dols. 3,	time, 14	hours.
" Poughkeepsie .	" 4,	" 17	"
" Esopus . . .	" 5,	" 20	"
" Hudson . . .	" $5\frac{1}{2}$,	" 30	"
" Albany . . .	" 7,	" 36	"

"'For places, apply to William Vandervoort, No. 48 Courtlandt Street, on the corner of Greenwich Street.[1]

"'Mr. Fulton's new-invented Steamboat, which is fitted up in a neat style for passengers, and is intended to run from New York to Albany as a Packet, left here this morning with 90 passengers, against a strong head-wind. Notwithstanding which, it was judged she moved through the waters at the rate of six miles an hour.'"[2]

[1] Copy of an advertisement taken from the "Albany Gazette," dated September, 1807.

[2] Extract from the "New York Evening Post," dated October 2, 1807.

During the next winter the "Clermont" was repaired and enlarged, and in the summer of 1808 was again on the route to Albany; and, meantime, the two new steamboats, the "Raritan" and the "Car of Neptune," had been built. In the year 1811 Fulton built the "Paragon."

Fulton patented novel details in steam-engines and steam-vessels in 1811, and thus secured some valuable property, though by no means sufficient to insure control of his routes. This he retained for a few years; but up to 1812, at least, there were continual attempts to establish rival lines, and vessels of all kinds, driven by engines of all sorts, practicable and impracticable, were built or proposed by ambitious inventors and "grasping capitalists." In the winter of 1812 an injunction was obtained from the courts in such terms that a perpetual injunction could be served on all the opposition lines, and Fulton was for a brief period allowed to pursue his own course in peace. A number of boats were now built for the rapidly increasing traffic of the rivers of the United States, and he placed some even on the "Father of Waters," where he fulfilled the prediction of his unfortunate predecessor, Fitch, whose remains now lie quietly beside one of its tributaries.

The table presented on page 135, given by his first biographer, shows the number and the principal dimensions of the boats built by Fulton, or from his plans, including the last three, which, though built after his death, are the most satisfactory of all.

Steam-vessels built in the City of New-York, under the Direction and Superintendence of Robert Fulton, or according to his Plan.

NAMES.	By whom built.	Dimensions.			Boilers.			Engine.		Water-wheel.			Tonnage.	When built.	Where employed.
		Length.	Depth.	Breadth.	Length.	Depth.	Breadth.	Cylinder.	Stroke.	Diameter.	Length of Bucket.	Dip.			
NORTH RIVER, or CLERMONT.	Charles Brown	133	7	18	20	7	8	24	4	15	4	2	160	1807	Hudson River
RARITAN.	Charles Brown.												120	1807	Raritan River.
CAR of NEPTUNE.	Charles Brown	175	8	24	18	8	9	33	4.4	14	4	2.4	295	1807	Hudson River.
PARAGON	Charles Brown	173	9	27	21	10	9	32	4	16	4.4	2.6	331	1811	Hudson River.
FIRE FLY.	Charles Brown.	100	7	19	14	9	8	20	[illegible]	12.6	3.6	2	[illegible]	1812	From New-York to Newburgh.
JERSEY FERRY boat.	Charles Brown.	78	7	32	20	9	9	20	4	12	4	2		1812	Ferry Company.
RICHMOND.	Charles Brown.	153	10	29	21	10	9	33	4.4	15	4.9	2.6	370	1813	Hudson River.
WASHINGTON.	Charles Brown.	135	9	25	20	9	8	26	4	14	4	2.3	275	1813	Potomac River.
YORK FERRY boat.	Charles Brown.	78	7	32	20	9	9	20	4	12	4	2		1813	Ferry Company.
NASSAU FERRY boat	Charles Brown.	78.6	7	33	20	8	10	20	4.6	12	4	2		1813	Brooklyn Comp'y.
FULTON.	A. & N. Brown.	134	9	30	20.4	8	9	36	4	15	4 10	2.6	327	1813	L. I. Sound.
FULTON THE FIRST.	A. & N. Brown.	156	20	56	22	8	12	48	5	16	14	4	2475	1814	Navy Yard.
OLIVE BRANCH.	Noah Brown.	124	8	30										1816	Between N. Y. and New-Brunswick
EMPEROR of RUSSIA.	Adam Brown.	134	9.6	30.6		has	three	36	5	16	4.10	2.6	330	1816	Undetermined.
CHANCELLOR LIVINGSTON.	Henry Eckford.	156	10.6	34	26	10	12	40	5	13	5.10	3	526	1816	Hudson River.

"Steam," says the "Gentleman's Magazine" for December, 1809, "has been applied in America to the purpose of inland navigation with the greatest success. The passage boat between New York and Albany is one hundred and sixty feet long, and wide in proportion for accommodations, consisting of fifty-two berths, besides sofas, etc., for one hundred passengers; and the machine which moves her wheels is equal to the power of twenty-four horses, and is kept in motion by steam from a copper boiler eight or ten feet in length. Her route is a distance of one hundred and fifty miles, which she performs regularly twice a week, and sometimes in the short space of thirty-two hours." An amazing tale!

According to Colden, the last boat which was constructed under Mr. Fulton's directions, and according to drawings and plans furnished by him, is that which, in 1816, navigated the sound from New York to New Haven. She was of nearly four hundred tons burden, built of uncommon strength, and fitted up with all conveniences and great elegance. She was the first steamboat with a round bottom like a sea-going ship. This form was adopted, because, for a great part of the route, she would be as much exposed as on the ocean. It was therefore, necessary, to make her a good sea-boat. She passed daily, and at all times of the tide, the then dangerous strait of Hell-Gate where, for a mile, she frequently encountered a current running at the rate of five or six miles an hour. For some distance she had within a few yards, on each side, rocks and whirlpools which rivalled Scylla

and Charybdis, even as they are poetically described. This passage, previously to its being navigated by this steamer, was supposed to be impassable except at the change of the tide; and many shipwrecks had been occasioned by a mistake in time. "The boat passing through these whirlpools with rapidity, while the angry waters foamed against her bows, and appeared to raise themselves in obstinate resistance to her passage, is a proud triumph of human ingenuity. The owners, as the highest tribute they had in their power to offer to his genius, and as an evidence of the gratitude they owed him, called her the "Fulton."[1]

A steam ferry-boat was built to ply between New York and Jersey City in 1812, and the next year two others, to connect with Brooklyn. These were "twin-boats" the two hulls being connected by a "bridge" or deck common to both. The Jersey ferry was crossed in fifteen minutes, the distance being a mile and a half. Fulton's boat carried, at one load, eight carriages, and about thirty horses, and still had room for three hundred or four hundred foot-passengers.

Fulton's description of one of these boats is as follows: —

"She is built of two boats, each ten feet beam, eighty feet long, and five feet deep in the hold; which boats are distant from each other ten feet, confined by strong transverse beam-knees and diagonal traces, forming a deck thirty feet wide and eighty feet long. The propelling water-wheel is placed between the boats to prevent it from injury from ice and shocks on

[1] Colden's Life of Fulton, p. 190.

entering or approaching the dock. The whole of the machinery being placed between the two boats, leaves ten feet on the deck of each boat for carriages, horses and cattle, etc.; the other, having neat benches and covered with an awning, is for passengers, and there is also a passage and stairway to a neat cabin, which is fifty feet long and five feet clear from the floor to the beams, furnished with benches, and provided with a stove in winter. Although the two boats and space between them gives thirty feet beam, yet they present sharp bows to the water, and have only the resistance in the water of one boat of twenty beam. Both ends being alike, and each having a rudder, she never puts about."[1]

Meantime, the War of 1812 was in progress, and Fulton designed a steam vessel-of-war, which was then considered a wonderfully formidable craft. Fulton proposed to build a vessel capable of carrying a heavy battery, and of steaming four miles an hour. The ship was fitted with furnaces for red-hot shot, and some of her guns were to be discharged below the water-line. The estimated cost was $320,000. The construction of the vessel was authorized by Congress in March, 1814; the keel was laid June 20, 1814, and the vessel was launched October 29 of the same year.

The "Fulton the First," as she was called, was then considered an enormous vessel. The hull was double, 156 feet long, 56 feet wide, and 20 feet deep, measuring 2,475 tons. In May the ship was ready for her en-

[1] Preble, page 59.

gine, and in July was so far completed as to steam, on a trial-trip, to the ocean at Sandy Hook and back, 53 miles, in eight hours and twenty minutes. In September, with armament and stores on board, the ship made for sea and for battle; the same route was traversed, the vessel making 5½ miles an hour. Her engine, having a steam-cylinder 48 inches in diameter and of 5 feet stroke of piston, was furnished with steam by a copper boiler 22 feet long, 12 feet wide, and 8 feet high, and turned a wheel, between the two hulls, 16 feet in diameter, with "buckets" 14 feet long, and a dip of 4 feet. The sides were 4 feet 10 inches thick, and her spar-deck was surrounded by musket-proof bulwarks. The armament consisted of 30 32-pounders, intended to discharge red-hot shot. There was one mast for each hull, fitted with lateen sails. Large pumps were carried, intended to throw streams of water on the decks of the enemy, with a view to disabling him by wetting his ordnance and ammunition. A submarine gun was to have been carried at each bow, to discharge shot weighing one hundred pounds, at a depth of ten feet below water.

This, for the time, tremendous engine-of-war was constructed in response to a demand from the citizens of New York for a means of harbour defence. They appointed what was called a Coast and Harbour Defence Committee; and this committee examined Fulton's plans, and called the attention of the General Government to them. The Government appointed a Board of Experts from among its most famous naval officers, including Commodore Decatur, Captains

Paul Jones, Evans, and Biddle, Commodore Perry, and Captains Warrington and Lewis. They reported unanimously in favour of the proposed construction, and set forth her advantages over all previously known forms of war-vessel. The citizens' committee offered to guarantee the expense of building the ship; and the construction was undertaken under the supervision of a committee appointed for the purpose, consisting of several then distinguished men, both military and naval. Congress authorized the building of coast-defence vessels by the President, in March, 1814, and Fulton at once started the work of construction, Messrs. Adam and Noah Brown building the hull, and the engines being placed on board and in working order within a year.

The death of Fulton took place in the year 1815, while in the height of his fame and of his usefulness. He had been called to Trenton, New Jersey, in January of that year, to give testimony before the State legislature in reference to the proposed repeal of laws which had interfered with the operation of the ferry-boats and other steam-vessels plying between the city of New York and the New Jersey shore. It happened that the weather was cold, he was exposed to its severity both at Trenton and, especially, crossing the Hudson River on his return, and took a cold from which he never recovered. He became apparently convalescent after a few days; but insisted on visiting the new steam-frigate too soon, to inspect work in progress there, and on his return home experienced a relapse, — his illness finally resulting in his death,

February 24, 1815. He left a wife (*née* Harriet Livingston) and four children, three of whom were daughters.

Robert Fulton died in the service of the United States government; and although engaged for years in devoting time and talents to the best interests of our country, still the public records show that the Government was indebted to his estate upwards of $100,000 for moneys actually expended and services rendered by him, agreeably to contract.[1]

When the legislature, then in session at Albany, heard of the death of Mr. Fulton, they expressed their sentiments of regret by resolving that the members of both houses should wear mourning for six weeks.

This is the only instance, according to Colden, up to that time, of such public testimonials of regret, esteem, and respect being offered on the death of a private citizen, who was only distinguished by his virtues, his genius, and his talents.

He was buried February 25, 1815. His funeral was attended by all the officers of the National and State governments then in the city, by the magistracy, the common council, a number of societies, and a greater number of citizens than had ever been collected on any similar occasion. When the procession began to move, and until it arrived at Trinity Church, minute-guns were fired from the steam-frigate and the Battery. His body is deposited in a vault belonging to the Livingston family.

[1] Reigart, p. 203.

Mr. Fulton is described as a tall man, about six feet in height, slender, but well proportioned. "Nature had made him a gentleman, and bestowed upon him ease and gracefulness." He had too much good sense to exhibit affectation, and confidence in his own worth and talents gave him a pleasing deportment in all companies. His features were strong and handsome; he had large dark eyes, a projecting brow, and features expressive of intelligence and thought; his disposition was mild yet lively, and he was fond of society. He conversed with energy, fluency, and correctness; and, owing more to experience and reflection than to books, he was often interesting in his originality.

In all his social relations he was kind, generous, and affectionate. His only use for money was to make it an aid to charity, hospitality, and the promotion of science. He was especially distinguished by constancy, industry, and that union of patience and persistence which overcame every difficulty.

Robert Fulton has never, even yet, received either in kind or degree the credit that is justly his due. Those members of the engineering profession who have become familiar with his work through the ordinary channels of information generally look upon him as a talented artist and fortunate amateur engineer, whose fancies led him into many strange vagaries, and whose enthusiastic advocacy of a new method of transportation — the success of which was already assured by the ingenuity and skill of James Watt, Oliver Evans, and John Fitch, and by the really

intelligent methods of those early professional engineers, the Messrs. Stevens — gave him the opportunity of grasping the prize of which Chancellor Livingston had secured the legal control. By such engineers as know only of his work on the Seine and the Hudson in the introduction of the steamboat, he is not considered as an inventor, but simply as one who profited by the inventions of others, and who, taking advantage of circumstances, and gaining credit which was not of right wholly his own, acquired a reputation vastly out of proportion to his real merits.

The layman, judging only from the popular traditions, and the incomplete historical accounts that have come to him, supposes Robert Fulton to have been the inventor of the steamboat, and on that ground regards him as one of the greatest mechanics and engineers that the world has seen.

The truth undoubtedly is, as we have now seen, that Fulton was not "the inventor of the steamboat," and that the reputation acquired by his successful introduction of steam-navigation is largely accidental, and is principally due to the possession, in company with Livingston, of a monopoly which drove from this most promising field those original and skilful engineers, Evans and the Stevenses. No one of the essential devices successfully used by Fulton in the "Clermont," his first North River steamboat, was new; and no one of them differed, to any great extent, from devices successfully adopted by earlier experimenters. Fulton's success was a commercial success purely. John Stevens had, in 1804, built a

successful *screw* steam-vessel; and his paddle-steamer of 1807, the "Phœnix," was very possibly a better piece of engineering than the "Clermont." John Fitch had, still earlier, used both screw and paddle. In England, Miller and Symmington and Lord Dundas had antedated even Fulton's earliest experiments on the Seine. Indeed, it seems not at all unlikely that Papin, a century earlier (in 1707), had he been given a monopoly of steam-navigation on the Weser or the Fulda, and had he been joyfully hailed by the Hanoverians as a public benefactor, as was Fulton in the United States, instead of being proscribed and assaulted by the mob who destroyed his earlier "Clermont," might have been equally successful; or it may be that the French inventor, Jouffroy, who experimented on the rivers of France twenty-five years before Fulton, might, with similar encouragement, have gained an equal success.

Yet although Fulton was not in any true sense "the inventor of the steamboat," his services in the work of introducing that miracle of our modern time cannot be overestimated; and, aside from his claim as the first to grasp success among the many who were then bravely struggling to place steam-navigation on a permanent and safe basis, he is undeniably entitled to all the praise that has ever been accorded him on such different ground.

It is to Robert Fulton that we owe the fact that to-day the rivers of our own country, and those of the world as well, are traversed by steamers of all sizes and all kinds, and by boats suited to every kind

of traffic; that the ocean floats, in every clime and in all its harbours, fleets of great steamers, transporting passengers and merchandise from the United States to Europe, from Liverpool to Hong-Kong, from London to Melbourne, traversing the "doldrums" as steadily and safely and as rapidly as the regions of the trades or either temperate zone. Steam-navigation without Fulton would undoubtedly have become an established fact; but no one can say how long the world, without that great engineer and statesman, would have been compelled to wait, or how much the progress of the world might have been retarded by his failure, had it occurred. The name of Fulton well deserves to be coupled with those of Newcomen and Watt, the inventors of the steam-engine; with those of George and Robert Stephenson, the builders of the railway; and with those of Morse and Bell, who have given us the telegraph and the telephone.

VII.

RIVER AND OCEAN STEAM-FLEETS.

WHILE Robert Fulton and his rivals in the United States were thus bringing into fruition the dreams of a century, inventors in other parts of the world were by no means idle. In Great Britain, Miller, Taylor, Symmington, and Lord Dundas had set an example which was well emulated by Henry Bell, of Glasgow, in 1812, when he built the "Comet" at Greenock, on the Clyde,—the first passenger steamer constructed in Europe. The boat was laid down in 1811, and completed Jan. 18, 1812, and proved to be a success. It was of 30 tons burden, 40 feet long, 10 feet beam, and driven by two pairs of paddle-wheels, worked by engines rated at but three horse-power.

Bell's boat was advertised as a passenger boat, to leave Greenock on Mondays, Wednesdays, and Fridays, for Glasgow, twenty-four miles distant, returning Tuesdays, Thursdays, and Saturdays. The fare was made "four shillings for the best cabin, and three shillings for the second." It was some months before the vessel became considered a trustworthy means of conveyance.

Bell constructed several boats in 1815, and with his success steam-navigation in Great Britain was fairly inaugurated. In 1814 there were five steamers,

all Scotch, regularly working in British waters. In 1820 there were thirty-four, — one half of which were in England, fourteen in Scotland, and the remainder in Ireland. Twenty years later, at the close of the period to which this chapter is especially devoted, there were about thirteen hundred and twenty-five steam-vessels in that kingdom, of which about a thousand were English, and two hundred and fifty Scotch.[1]

During this period the introduction of the steamboat on the great rivers of the United States was one of the most notable events of history. Inaugurated by Evans, the building of steam-vessels once begun, never ceased; and not long after Fitch's burial on the bank of the Ohio, his last wish — that he might lie "where the song of the boatman would enliven the stillness of his resting-place, and the music of the steam-engine soothe his spirit" — was fulfilled.

Nicholas J. Roosevelt was the first to take a steamboat down the Ohio and Mississippi. His boat was built at Pittsburgh in 1811 from Fulton's plans. It was called the "New Orleans," of about two hundred tons burden, and was propelled by a stern-wheel, assisted, at times, by sails on two masts. The hull was 138 feet long, and 30 feet beam. The cost of the boat, including engines, was about $40,000. The builder, with his family, an engineer, a pilot, and six "deck hands," left Pittsburgh in October, 1811, reached Louisville in seventy hours (about ten miles an hour), and New Orleans in fourteen days, steaming from Natchez.

The next steamers built on Western waters were

[1] Thurston's History of the Steam-Engine, p. 249

probably the "Comet" and the "Vesuvius." The "Comet" was finally laid aside, and the engine used to drive a saw-mill; and the "Vesuvius" was destroyed by the explosion of her boilers. In 1813 there were two shops at Pittsburgh building steam-engines, and it is stated that as early as 1840 there were a thousand steamers on the Mississippi and its tributaries.

In the "Washington" (built at Wheeling, Va., in 1816, by Capt. H. M. Shreve) the boilers, previously placed in the hold, were carried on the main-deck, and a "hurricane-deck" was built over them. Two horizontal direct-acting engines were adopted instead of the single upright engine used by Fulton, and were driven by high-pressure steam without condensation. The engines, one on each side of the boat, were attached to cranks placed at right angles. He adopted a cam cut-off, and the flue-boiler of Evans. At that time the voyage to New Orleans from Louisville occupied three weeks, and Shreve was made the subject of many witticisms when he predicted that the time would be shortened to ten days. It is now made in four days.[1]

The death of Fulton left the work of introduction of the steamboat on the rivers of the country in the hands of others no less able and enterprising than he; and the expiration or repeal of the provisions giving the monopoly of steam-navigation on the Hudson to his company permitted them to proceed with their plans undisturbed. The courts ruled, finally, that only the General Government could control the navigation of tide-waters and navigable rivers communi-

[1] Thurston's History of the Steam-Engine, p. 249.

cating directly with the sea; the provisions for rewarding inventors by a patent-system covering the whole country and administered by the United States patent office gave good reason for withdrawing the special laws previously sustained by the several States, for giving this kind of monopoly, where legal, even; and the whole river-system of the country was open to all.

The steam-navigation of the Hudson soon fell largely into the hands of the Stevens, father and sons; and they, mainly through the ingenuity and skill of Robert L. Stevens,[1] soon established what has come to be recognized as a peculiarly admirable type of craft for these long inland routes.

Referring to his valuable services, President King, then of Columbia College, who seems to have been the first to appreciate the original invention and the excellence of the engineering of this family, in a lecture delivered in New York, in 1851, gave a connected and probably accurate description of their work.

Young Stevens began working in his father's machine-shop when a mere boy, and acquired at a very early age familiarity with details of work and of business. It was he who introduced the "hollow water-line" in the "Phœnix." In the same vessel he adopted a feathering paddle-wheel and the guard-beam now universally seen in river steamboats.

The "Philadelphia" was built in 1813, and the

[1] The Author has compiled a memorandum of the work of this remarkable engineer, the perusal of which may give some idea of the ingenuity and versatility of his talents. See the Journal of the Franklin Institute, 1874.

young engineer introduced several new devices, including screw-bolts in place of "tree-nails," and diagonal knees. Two years later he altered the engines, and arranged them to work steam expansively. A little later he began using anthracite coal. Stevens was the first of whom we have record who was thoroughly successful in using the new fuel. Mr. R. L. Stevens's labours and inventions in mechanics, should have more fitting commemoration than can be given in any passing notice. Of some of them the following is the chronological record: —

1808. Hollow or concave water-lines in the bow were introduced for the first time in the steamboat "Phœnix;" these lines, under the name of "wave lines," are now claimed as a recent application. On the same vessel, in 1809, he first used the feathering-wheel with vertical buckets on pivots.

1809. He suspended the guard-beam by iron rods from above, as is now universally done in river steamers.

1813-14. The war with England being in progress, he invented the elongated shell, to be fired from ordinary cannon. Having perfected this invention, he sold the secret to the United States, after experiments so decisive as to leave no doubt of the efficacy of such projectiles. In one of these experiments made at Governor's Island in the presence of officers of the army, a target of white oak, four feet thick, was completely destroyed by a shell weighing two hundred pounds and containing thirteen pounds of powder; the opening made was large enough, as the certificate

of the officer commanding, Colonel House, stated, for a man and horse to enter.

These shells were said to be free from the danger accompanying ordinary shells, for they were hermetically sealed. Some, after being kept twenty-five years, were tested by exploding gunpowder under them, and then taken to high places and let fall on rocks below, without causing them to explode. After this they were plunged into water, and finally being put into the gun, were fired, and upon striking, exploded with devastating effect.

1813. First to fasten planks and braces of steamboats with screw-bolts, and to place diagonal knees inside.

1815. First to use steam expansively in the "Philadelphia."

1818. First to burn anthracite coal in a cupola furnace, and subsequently to introduce this fuel in steamers; — the "Passaic" being the earliest.

1822. He made the skeleton wrought-iron walking-beam now in general use.

1824. First to place the boilers on the guards, and to divide the buckets on the wheel.

1827. First, on steamboat "North America," to apply artificial blast to the furnace, and in the same boat to apply what is technically known as the "hog-frame," consisting of large timbers along the sides, to prevent the boat from being "hogged."

1828. First to apply steel spring bearings, under the centre of the paddle-shaft of the steamer "New Philadelphia."

1832. First to introduce perfectly balanced valves, which enabled one man to work the largest engine with ease. In the same year he used braces to the connecting-rod, thus preventing its tremulous motion.

1832–33. Constructed a boat capable of navigating through heavy ice. In the same year he introduced tubular boilers.

1840. Improved the packing of pistons for steam-engines by using the pressure of steam to retain the packing-ring against the surface of the cylinder.

1841. The Stevens Cut-off, by means of main valves worked by two eccentrics, invented by R. L. Stevens and his nephew F. B. Stevens. In the same year he invented and applied on the Camden and Amboy railroad the double-slide cut-off for locomotives and large engines, and improved locomotives by using eight wheels, and with increased adhesion was enabled to turn short curves with little friction on the flanges; also used anthracite as a fuel to great advantage on the heavy engines.

1842. Having contracted to build for the United States government a large war-steamer, shot and shell proof, R. L. Stevens built a steamboat at Bordentown for the sole purpose of experimenting on the forms and curves of propeller-blades, as compared with side-wheels, and continued his experiments for many months. While occupied with this design he invented about 1844, and took a patent for, a mode of turning a steamship of war by means of a cross propeller near the stern, so that if one battery were disabled, she might promptly present the other.

1848. This year he succeeded in advantageously using anthracite in fast passenger locomotives.

1849 witnessed the successful application of air under the bottom of steamer "John Neilson," whereby friction is so much diminished, that she actually attained, as stated by President King, the speed of twenty miles an hour. This was the invention of R. L. Stevens and F. B. Stevens.

The name of Robert L. Stevens will long be remembered as that of one of the greatest of American mechanics, the most intelligent of naval architects, and as the first, and one of the greatest, of those to whom we are indebted for the beginning of the mightiest of revolutions in the methods and implements of modern naval warfare. American mechanical genius and engineering skill have rarely been too promptly recognized, and no excuse will be required for an attempt (which it is hoped may yet be made) to place such splendid work as that of the Messrs. Stevens in a light which shall reveal both its variety and extent and its immense importance.

As early as August, 1841, his brothers, James C. and Edwin A. Stevens, representing Robert L., addressed a letter to the Secretary of the Navy, proposing to build an iron-clad vessel of high speed, with all its machinery below the water-line, and having submerged screw propellers. The armament was to consist of powerful breech-loading rifled guns, provided with elongated shot and shell. In the year 1842, having contracted to build for the United States government a steamer on this plan, Robert L.

Stevens built his steamboat at Bordentown, for the sole purpose of experimenting on the forms and curves of propeller-blades, as compared with side-wheels, and, as already stated, worked many months. After some delay, the keel of an iron-clad was laid down. This vessel was to have been 250 feet long, 40 feet beam, and 28 feet deep. The machinery was 700 horse-power. The plating was proposed to be $4\frac{1}{2}$ inches thick, — the thickness adopted ten years later by the French.

In 1854 such marked progress had been made that Mr. Stevens was no longer willing to proceed with the original plans, and work, which had progressed very slowly and intermittently, was stopped entirely; and in 1854 the keel of a ship of much greater size and power was laid down. The new design was 415 feet long, of 45 feet beam, and of something over 5,000 tons displacement, while its machinery was of 8,600 horse-power. The thickness of armor proposed was $6\frac{3}{4}$ inches. The engines were to drive twin screws, propelling the vessel twenty miles or more an hour.

The remarkable genius of Stevens is in no way better exemplified than by the accuracy with which, in this great ship, those forms and proportions were adopted which are now, many years later, recognized as most correct under similar conditions. The lines of the vessel were beautifully fair and fine, — what J. Scott Russell called "wave lines," or trochoidal lines, and are now known to be the best possible for easy propulsion.

The death of Robert L. Stevens occurred in April, 1856, when the hull and machinery were practically finished, and it only remained to add the armour-plating, and to decide upon the form of fighting-house and the number and size of guns. The construction of the vessel then ceased and it was never completed.

From the time of Fulton, the progress of steam-navigation on the rivers of the United States was rapid. The "Phœnix" of Stevens opened the Delaware, and the boats of Fulton himself and his successors introduced the new system of transportation on the Connecticut and Long Island Sound. The venturesome voyage of Roosevelt, in 1811, down the Ohio and the Mississippi, was made on the first of the steam-vessels, since numbered by thousands, on the western waters. His boat, the "New Orleans," ran for years between the city of that name and Natchez. The "Enterprise," in 1814, took part in the defence of New Orleans by General Jackson, and afterward ascended the "Father of Waters," reaching Louisville in twenty-five days from New Orleans. A quarter of a century later the trip was made in less than a week; and in 1850, four days was considered good time for the same voyage.

By the year 1860 there were about one hundred and twenty-five steamboats on the Ohio and Mississippi and their tributaries, some of which made twenty miles an hour or more. All were paddle-boats, and usually stern-wheelers, — that type of vessel being found more manageable on those rivers, — although

the side-wheeler became the only form of steamboat on the rivers and sounds of the coast for many years, and until the advent of the screw.

The growth of steam-navigation in Great Britain was less rapid than in the United States; but as early as 1815, about the time of Fulton's death, there were ten steamers on the Clyde, and seven or eight on the Thames. The "Argyle" was the first sea-going steamer built in British waters. This vessel made a voyage from the Clyde, where she was built, to London, where she was to be employed, after a year of service between Glasgow and Greenock. The voyage was made in about a month, in a stormy season, and the Thames was safely reached, the vessel then entering upon her regular scheduled trips between London and Margate. In 1816 the steamer "Majestic," built at Ramsgate for the purpose, made her first trips between Brighton and Havre, and from Dover to Calais. It was in this year that Captain Bunker, who had served on the "Phœnix," was given command of the steamer "Connecticut," and established the first line of boats on Long Island Sound, between New York and New Haven and New London. From this date on, British steamers began to appear in all the principal harbours of Great Britain, and lines to Ireland and to the French and Dutch coasts were rapidly created.

Progress continued to be most rapid in the United States, however. Cornelius Vanderbilt made his first venture in the "Bolona," built by Lawrence in 1817; and the fortunes of that family and the steam-navi-

gation of the Hudson and of the sounds adjacent flourished together. The trip to Providence from New York was made, in those days, in about twenty hours, and the price paid was ten dollars, including berths and meals.

About 1821 Robert L. Thurston, John Babcock, and Capt. Stephen T. Northam, of Newport, R. I., commenced building steamboats, beginning with a small craft intended for use at Slade's Ferry, near Fall River. They afterward built vessels to ply on Long Island Sound. One of the earliest was the "Babcock," built at Newport in 1826. The engine was built by Thurston and Babcock, at Portsmouth, R. I. They were assisted in their work by Richard Sanford, and with funds by Northam. The engine was of twelve inches diameter of cylinder, and four feet stroke of piston. The boiler was a form of "pipe-boiler," patented (1824) by Babcock. The water used was injected into the hot boiler as fast as required to furnish steam, no water being retained in the steam-generator. This boat was succeeded, in 1827–1828, by a larger vessel, — the "Rushlight," — for which the engine was built by James P. Allaire, at New York, while the boat was built at Newport. The boilers of both vessels had tubes of cast-iron. The smaller of these boats was of eighty tons burden. It steamed from Newport to Providence, 30 miles, in $3\frac{1}{2}$ hours, and to New York, a distance of 175 miles, in 25 hours, using $1\frac{3}{4}$ cords of wood.[1] Thurston and Babcock removed to Providence, where the latter died. Thurston continued to build steam-engines

[1] History of the Growth of the Steam-Engine, p. 281.

there nearly a half-century, dying in 1874. The establishment founded by him, after various changes, became the present Providence Steam-Engine Works.

This "pipe-boiler" was intended, as was the earlier construction of the elder Stevens, for high pressures, which now came into use. As early as 1817, according to the testimony of Seth Hunt before a parliamentary committee in England, Oliver Evans had successfully carried pressures of one hundred and forty and one hundred and sixty pounds of steam; and now James P. Allaire, of New York, started on the same line of improvement in economy. Watt had showed, both by his logical deduction, exemplified in his patent of 1769, and by actual construction of engines some years later, that the expansive action of steam was an available source of economy, and had beaten Hornblower, whose compound engine was expressly constructed for the purpose of securing that advantage. Allaire used the compound engine, with steam at a pressure of one hundred pounds and upward, in 1825, for the first time in steam-navigation. The first of his vessels of this class was the "Henry Eckford," and this was succeeded by others, one of which, the "Sun," made the run from New York to Albany in twelve hours, eighteen minutes. Erastus W. Smith afterward introduced the compound engine on the Great Lakes, and they were still later introduced into British steamers by John Elder and his partners. The machinery of the steamer "Buckeye State" was constructed at the Allaire Works, New York, in 1850, from the designs of John Baird and Smith, the latter being the designing and constructing engineer. The steamer was placed on the route between

Buffalo, Cleveland, and Detroit, in 1851, with most satisfactory results, consuming less than two thirds the fuel required by a similar vessel fitted with the single-cylinder engine. The steam-cylinders were placed one within the other, the low-pressure exterior cylinder being annular. They were 37 and 80 inches in diameter, respectively, with a piston-stroke of 11 feet. Both pistons were connected to one cross-head, and the arrangement of the engine was that of the common beam-engine. The steam-pressure was seventy to seventy-five pounds, — about the maximum pressure adopted a quarter of a century later on trans-Atlantic lines.

The French engineers were but little behind their American rivals in this race, and built a steamboat with compound engines, in 1829, called the "Union," from the plans of M. Hallette, of Arras. Steam was carried at sixty-five to seventy pounds pressure.

As illustrating the latest form of the lineal successor of Fulton's "Clermont," we may take the Hudson River steamer "New York," plying on the same route. The hull of this vessel was built at Wilmington, Del., by The Harlan and Hollingsworth Co., of iron throughout. The dimensions are as follows:

Length on the water-line . .	301 feet.
Length over all	311 "
Breadth of beam, moulded . .	40 "
Breadth of beam, over guards	74 "
Depth, moulded	12 " 3 ins.
Draft of water	6 "
Tonnage (net, 1091.89) .	1552.52

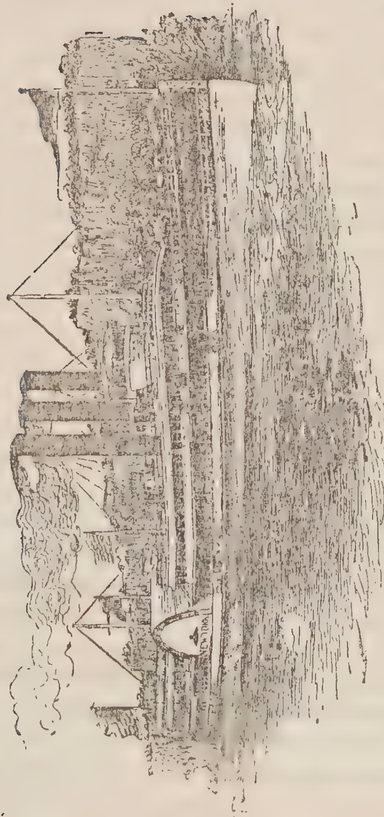

Fig. 17.—The "New York."

The machinery was built by the W. & A. Fletcher Company, North River Iron Works. The engine is a standard American beam-engine, with a cylinder seventy-five inches diameter and twelve feet stroke of piston, with Stevens's cut-off. The use of a surface condenser, instead of a jet condenser, in this river steamer, is a change made to overcome the evil of using mixed salt and fresh water in the boilers.

Another is the adoption of "feathering-wheels" instead of the radial wheels, with fixed buckets or floats. These wheels are 30 feet 2 inches diameter outside of buckets. There are twelve curved steel buckets to each wheel. Each bucket is 3 feet 9 inches wide and 12 feet 6 inches long, with an angle iron 3 x 5 inches on each end. The wheels are overhung, or have a bearing outboard on the hull only. The feathering is done in the usual manner by means of driving and radius bars, operated by a centre placed eccentric to the shaft and held by the A frame on the guard. They were introduced in the "New York" for the purpose of gaining speed, and the trial-trips show that the builders' expectations were not groundless.

Absence of jar is another great gain obtained by the use of these wheels, and the comparatively thin buckets enter the water so smoothly that the boat i without the shake so common with the ordinary wheels.

Steam is supplied to the engine by three return flue boilers, each 9¼ feet diameter of shell, 11 feet width of front, and 33 feet long. These boilers are con-

structed for a working pressure of fifty pounds per square inch. Each boiler has a grate surface of 76 square feet, or 228 square feet in all, and with the forced draught produce 3,850 horse-power.

Another measure of safety is the steam steerer, which has been put on so that the boat can be handled with the quick and easy precision due to this improvement.

The exterior is, as usual in this class of steamers, of pine painted white, relieved with tints and gold. The interior is finished in cabinet work, and is all hard wood, — ash being used forward of the shaft on the main deck and mahogany aft and in the dining-cabin.

The construction of steamers of recent design for lake and sound routes, as between New York and New England, on Long Island Sound, is exemplified by that of the "Puritan."

"The 'Puritan' has principal dimensions as follows: Length, over all, 420 feet; length on the water-line, 404 feet; width of hull, 52 feet; extreme breadth over guards, 91 feet; depth of hull amidships, 21 feet, 6 inches; height of dome from base-line, 63 feet; whole depth, from base-line to top of house over the engine, 70 feet. Her total displacement is 4,150 tons, and her gross tonnage 4,650 tons.

"The 'Puritan' is fireproof and unsinkable, has a double hull divided into fifty-nine water-tight compartments. In the fastenings of her steel hulls and compartments, there have been used seven hundred thousand rivets. Her decks are of steel, wood covered.

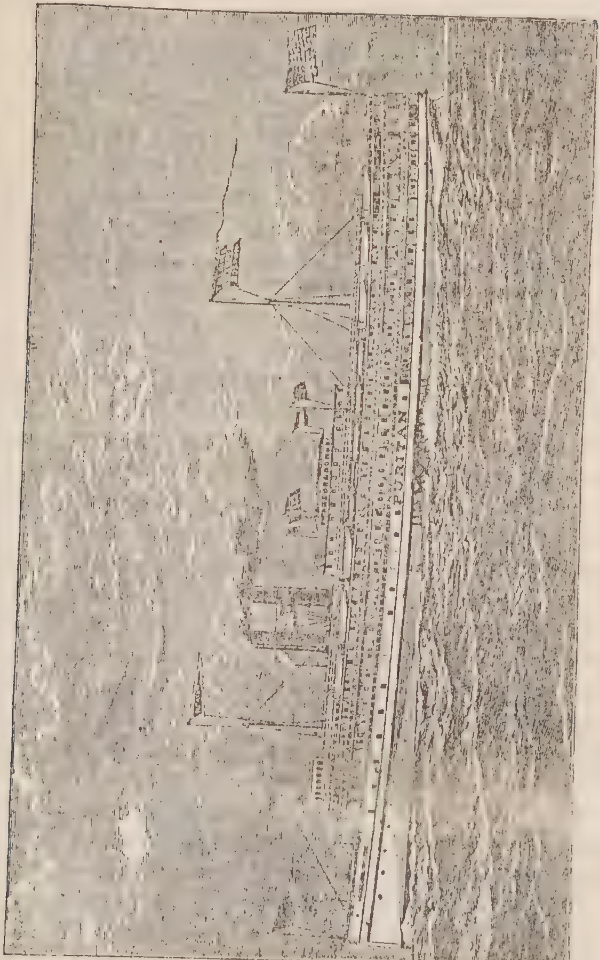

Fig. 18. — The "Puritan."

Her masts are of steel, and hollow, to serve as ventilators, and are twenty-two inches in diameter. Her paddle-wheels are encased in steel.

"The 'Puritan's' hull is made of 'mild steel,' which metal, weight for weight, is some twenty per cent stronger than iron, with twenty-five per cent reduction of area, according to the best Góvernment test. "Her wheels are of steel, and are 35 feet in diameter outside the buckets. The buckets are 14 feet long and 5 feet wide, each bucket of steel $\frac{7}{8}$ inch thick, and weighing 2,800 pounds without rocking-arms and brackets attached. The total weight of each wheel is 100 tons. "She has eight steel boilers of the Redfield return tubular type, and the maximum working pressure is one hundred and ten pounds to the square inch. This fact illustrates the great advances made since the days of Fulton in the safe employment of high-pressure steam; and the standard construction continually tends toward still higher tension.

"The 'Puritan' has a compound, vertical beam, surface-condensing engine of 7,500 horse-power. The high-pressure cylinder is 75 inches in diameter, and 9 feet stroke of piston. The low-pressure cylinder is 110 inches in diameter, and 14 feet stroke of piston. A horse and wagon could be driven through this cylinder if laid on its side. The surface condenser has 15,000 square feet of cooling surface and weighs 53 tons. Of condenser tubes of brass there are $14\frac{1}{2}$ miles in the 'Puritan.' Her working beam is the largest ever made, being 34 feet in length from

centre to centre, 17 feet wide, and weighing 42 tons. When it is considered that the section of beam-strap measures $9\frac{1}{2} \times 11\frac{1}{4}$ inches, one may get an idea of the enormous strain and the strength of resistance of this beam. The main centre of the beam is 19 inches in diameter in bearing. The shafts are 27 inches in diameter in main bearing, and 30 inches in gunwale bearing, and are the largest ever made in this country. They weigh 40 tons each. The cranks weigh 9 tons each. The crank-pin is enormous, the bearing being 10 inches in diameter and 22 inches long.

"There are two centrifugal circulating pumps, each capable of throwing ten thousand gallons per minute. Besides these there are three other large pumps, with a combined capacity of two thousand gallons per minute. Novel features are the three steam capstans, — one forward and one on each quarter, — to be used in docking the boat; each capstan has a double cylinder engine, each cylinder twelve inches in diameter and fourteen inches stroke. She has two Sturtevant blowers, furnishing fresh air for fire-room, each capable of fifty thousand feet per minute. She will burn about one hundred and twenty tons of coal on the trip from New York to Fall River and back.

"From stem to stern, and in every nook and corner of the ship, the electric wire is to be found. In all, there are twelve miles of this wire; and including annunciators, fire-alarm, etc., there are twenty miles of wire on the ship, and twelve thousand feet of steam pipe. There are capacious gangways, grand and im-

posing staircases heavy with brass and mahogany, lofty cornices, and ceilings supported by tasteful pilasters, the tapering columns of which, in relief, flank exquisitely tinted panelling throughout the length of her grand and minor saloons. And over all this artistic work and exuberant colouring, the incandescent electric light sheds its soft rays. Every convenience known to civilization, and which can contribute to the ease and comfort of the traveller on land or when afloat, is included in the internal arrangements of this floating caravansary. The artistic and luxuriant sense of the beholder is also abundantly appealed to. The 'Puritan' has in all, three hundred and sixty-four staterooms.

"Some idea of the immense amount of finish in the different departments may be obtained when it is understood that in the gilding alone 185,000 gold leaves, each $3\frac{3}{8}$ inches square, were used. In painting the ship nearly one hundred thousand pounds of lead were expended."[1]

[1] Fall River Line Gazette.

VIII.

OCEAN STEAMERS. — THE OUTLOOK.

Steam-navigation on the ocean had a real beginning about 1840, and this may be taken as the period of introduction of the screw-propeller, — two events of supreme importance in the history of the art which the work of Fulton had so effectively promoted. Tentatively, the steam-navigation of the ocean had begun but little later than the navigation of the rivers and harbours of the United States. The ocean voyage of Robert L. Stevens was soon followed by those of Bell and Dodd in Great Britain; and by 1815 it was recognized as a possibility that long voyages might be undertaken by larger vessels. The first transatlantic voyage was made by the "Savannah," in 1819, partly by steam, in part by sail. This ship is now famous as the pioneer in this great traffic. The following description has been elsewhere given by the Author:[1]

The "Savannah" measured three hundred and fifty tons, and was constructed by Crocker & Fickett, at Corlear's Hook, N. Y. She was purchased by Mr. Scarborough, of Savannah, who placed Captain Moses Rogers, previously in command of the "Clermont"

[1] History of the Steam-Engine, p. 285, *et seq.*

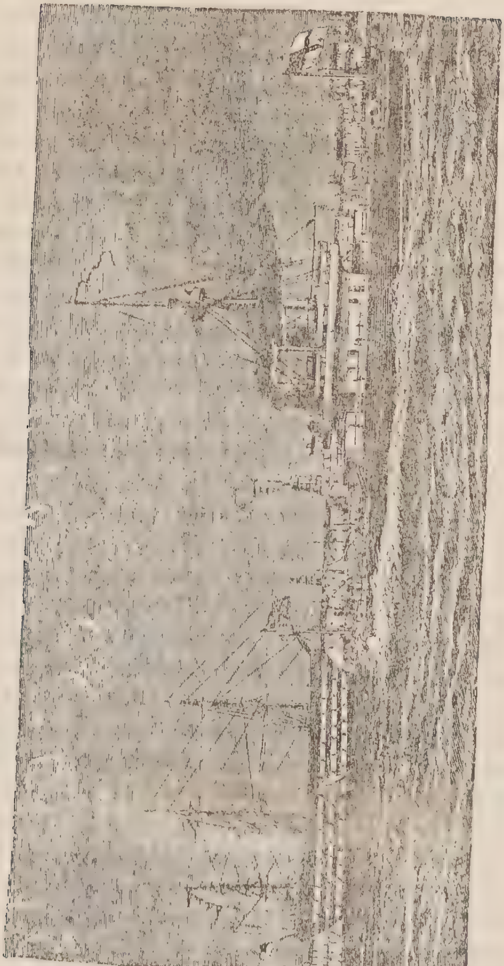

Fig. 19. — Old Ship-of-the-Line and Modern Ironclad.

and of Stevens's boat, the "Phœnix," in charge. The ship was fitted with steam machinery and paddle-wheels, and sailed for Savannah, April 27, 1819, making the voyage successfully in seven days. From Savannah, the vessel sailed for Liverpool, May 26, and arrived at that port June 20. During this trip the engines were used eighteen days, and the remainder of the voyage was made under sail. From Liverpool the "Savannah" sailed, July 23, for the Baltic, touching at Copenhagen, Stockholm, St. Petersburg, and other ports. At St. Petersburg, Lord Lyndock, who had been a passenger, was landed; and on taking leave of the commander of the steamer the distinguished guest presented him with a silver tea-kettle, suitably inscribed with a legend referring to the importance of the event which afforded him this opportunity. The "Savannah" left St. Petersburg in November, passing New York December 9, and reaching Savannah in fifty days from the date of departure, stopping four days at Copenhagen, Denmark, and an equal length of time at Arundel, Norway. Several severe gales were met in the Atlantic, but no serious injury was done to the ship.

The "Savannah" was a full-rigged ship. The wheels were turned by an inclined direct-acting low-pressure engine, having a steam-cylinder forty inches in diameter and six feet stroke of piston. The paddle-wheels were of wrought-iron, and were so arranged that they could be detached and hoisted on board when found advisable. After the return of the ship to the United States the machinery was removed,

and was sold to the Allaire Works, of New York. The steam-cylinder was exhibited by the purchasers at the World's Fair at New York, thirty years later. The vessel was employed as a sailing-vessel on a line between New York and Savannah, and was finally lost in the year 1822.

Later, the "Enterprise" made a voyage (1825) to India, under steam and sail as the weather and circumstances permitted; and still other vessels were built, using "auxiliary" engines, as they were called; but even as late as 1838 there were grave doubts expressed by eminent authorities of the feasibility of making long voyages by steam alone. These doubts were, however, set at rest in that year by the crossing of the Atlantic by two steamers almost simultaneously, — the "Sirius" and the "Great Western." The latter was a large vessel for those days, and nearly double the size and power of the other. The "Great Western" was of 1,350 tons burden and 450 horse-power; the "Sirius" was of 700 tons and 250 horse-power

The "Sirius" sailed from Cork on the 4th and the "Great Western" from Bristol on the 8th of April, both arriving in New York on the same day, — April 23, 1838, — the one in the morning, the other in the afternoon. These vessels were placed on the route in the interests, respectively, of the British and American Steam Navigation Co., and of the Great Western Railway of Great Britain. Both ships returned safely, making good time; and the larger was kept on the line for some years, making many successful voyages. The other craft was deemed too small

for the route and was taken off and placed on a line between Dublin and Cork. Other ships were soon built for this trade, and the transoceanic lines were gradually established, never again to be given up. As may well be imagined, the appearance of the two pioneers in New York harbour was a most impressive event, and awakened the greatest enthusiasm on both sides the Atlantic. The formation of the still-existing

Fig. 20. — The "Pacific," 1851.

Cunard Line immediately followed; its first vessel, the "Britannia," sailing for New York on the 4th of July, 1840. Three sister ships followed; and the four steamers continued in service until the success of the enterprise was so far assured as to justify the building of larger and more powerful vessels. These four ships had an aggregate of about forty-six hundred tons burden, — about one half the tonnage of single vessels now on transatlantic lines. These vessels and the ships of the first large American company, the Collins Line,

organized about 1850, were all paddle-steamers with side-lever engines, like that illustrated in figure 21. They were first built, it is said, by Messrs. Maudsley, Sons, & Field, about 1835; but that here illustrated was designed by Mr. Charles Copeland, of New York, for the "Pacific," one of the Collins steamers.

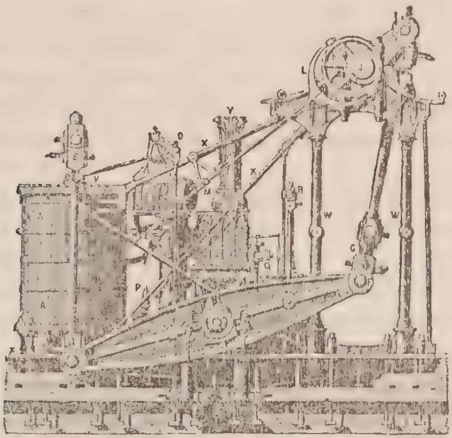

Fig. 21. — The Side-Lever Engine, 1849.

This steamer was built at New York, — the hull by William Brown, and the machinery by the Novelty Iron Works. The length of the hull was 276 feet, its breadth 45 feet, and the depth of hold $31\frac{1}{2}$ feet. The width over the paddle-boxes was 75 feet. The ship measured 2,860 tons. The form of the hull was such as best adapted the ship for high speed. The main "saloon" was about 70 feet long, and the

dining-room was 60 feet in length and twenty feet wide. The staterooms accommodated 150 passengers. These vessels inaugurated our present wonderful system of passenger-transportation.[1] The engines were of the side-lever type, as illustrated in Figure 21.

In this engine the piston-rod was attached to a cross-head, from which, at each side, links *B C*, connected with the side-lever, *D E F*. The latter vibrated about a main centre at *E*; from its other end a connecting-rod, *H*, led to the cross-tail, *W*, connected to the crank-pin, *I*. The condenser, *M*, and air-pump, *Q*, were between the cylinder, *A*, and the crank, *I J*.

The Collins Line proved a failure; but it was very largely a consequence of a series of misfortunes, for which neither the management nor the officers of the ships were held accountable. Ship after ship was lost, and the costs of operation in competition with the British lines, which were subject to far less expense, proved to be unexpectedly large. It is also probable that the general introduction of the screw, after these ships had been built as paddle-steamers, had something, perhaps much, to do with the final breaking down of so expensive and burdensome a line. The screw-propeller had by this time become an undeniable success in competition with the paddle in ocean steaming; and screw-vessels now rapidly displaced those propelled by paddle-wheels.

The screw-propeller, proposed by Bernouilli and by Watt, used successfully by Fitch and by Stevens and

[1] History of the Steam-Engine, p. 290.

Smith, and a little later (1812) by Trevithick, was finally brought into use for general purposes by Francis Pettit Smith in Great Britain, and by John Ericsson in the United States, after the latter had made an experimental success but a commercial failure of it in England. Ericsson's patent on his screw was issued from the British patent office in 1836. His boat, built in that year, was found to be capable of doing good work as a "tug" on the Thames, making ten miles an hour, running free, and towing large vessels at the rate of five to seven miles an hour. The British Admiralty, with customary conservatism, refused to adopt Ericsson's plans, and he was persuaded by Captain Stockton, an enterprising American naval officer, to go with him to the United States, and there endeavour to interest the Navy Department in his inventions. A screw-vessel, the "Stockton," was accordingly built in England and sent over to the United States in 1839; and Ericsson followed, to build other vessels for Stockton and his partners in the venture. The "Stockton" remained in service on the Delaware and Raritan Canal, under the name of the "New Jersey," for many years.

After the departure of Ericsson a company was formed in England to work the patents of Smith; and this company built the "Archimedes," the trial trip being made October 14 of that year. This boat made nearly ten miles an hour; and the British Admiralty at last began to take some interest in the subject, and subsequently adopted the screw for naval purposes. Meantime, also, Congress had authorized the

construction of new vessels, and Ericsson was allowed to introduce his screw and his engines into one of them, — the "Princeton." This was the first steamer built for war purposes which was fitted with a screw-propeller. She was large for the time, — about one thousand tons displacement, — and all the machinery was placed under the water-line for the first time also.

In reporting on the performance of this ship, Captain Stockton, who was the first commander, recites the advantages possessed by the steamer in consequence of the facts that her machinery is out of reach of shot; that no paddles are in sight; that she has clear decks; and that, burning anthracite coal, no smoke is visible; he then goes on to repeat, substantially, the idea of Fulton, saying, "The improvements in the art of war effected on board the 'Princeton' may be productive of more important results than anything that has occurred since the invention of gunpowder. The numerical force of other navies, so long boasted, may be set at naught; the ocean may again become neutral ground; and the rights of the smallest, as well as the greatest nations, may once more be respected." The hull of the vessel was condemned in 1849, and the ship broken up. A second hull was built, fitted with the same machinery, and given the same name, in 1851, but was less satisfactory, performed little service, and was sold out of the service in 1867. Since the days of the "Princeton," all navies have adopted the screw-propeller, and all naval fleets are steam-fleets.

The screw was found to possess many advantages

over the paddle-wheel. The cost of machinery was greatly reduced; the expense of maintenance in working order was, however, somewhat increased. The latter disadvantage was, nevertheless, compensated by an immense increase in the economy of power for ship-propulsion, which marked the substitution of the new machinery.

When a ship is under way, the motion of the vessel creates a current of water in the direction in which the ship is moving, following the ship for a time, and finally losing all motion by contact with the surrounding mass of water. All the power expended in the production of this great stream is, in the paddle-steamer, lost. In screw-steamers, however, the propelling instrument works in this following current; and the tendency is to bring the fluid to rest, taking up, and thus restoring usefully, a large part of that energy which would otherwise have been lost. The screw is covered by the water, and acts with comparative efficiency in consequence of its submersion. The rotation of the screw is rapid and smooth also, and this permits the use of small, light, fast-running engines. The latter condition leads to economy of weight and space, and saves not only the cost of transportation of the excess of weight of the larger kind of engine, but leaving so much more room for cargo, the gain is found to be a double one. Still further: the quick-running engine is, other things being equal, the most economical, and thus expense is saved, not only in the purchase of fuel, but in its transportation; and additional gain is derived from the increased amount

of paying cargo which the vessel is thus enabled to carry.[1]

Since the days of Ericsson's great success in the introduction of the screw-propeller and the organization of steam-fleets, there have been two great improvements in the steam-engine, and two important changes in naval construction. The first two are the general introduction of the surface-condenser, and the use of the compound engine at sea; the second two are the building of the iron-clad fleet, and the construction of Ericsson's greatest invention, the "Monitor." During these fifty years, also, the steam-fleets of the merchant navies of the world have become enormously increased in numbers, their vessels have grown to tremendous size, and their machinery has more than proportionally gained in power, driving their great hulls through the heaviest seas with the speed of the railway train on land.

The change from the side-lever single-cylinder engine, with jet-condenser and paddle-wheels, to the direct-acting compound engine, with surface-condenser and screw-propellers, has occurred within this period. Builders slowly learned the principles governing expansion in one or more cylinders; and the earlier engines were often made with a high and low pressure cylinder working on the same rod, each machine consisting of four steam-cylinders. It was at last discovered that a high-pressure single-cylinder engine exhausting into a separate larger low-pressure engine might do as well, and the compound engine

[1] History of the Steam-Engine, p. 297.

became as simple as the type of engine which it displaced.

The advantage of introducing such engines at sea is considerably greater than on land. The coal carried by a steam-vessel is not only an item of great importance in consequence of its cost, but it represents so much non-paying cargo, and is to be charged with the full cost of transportation in addition to first cost and the loss of profit on the freight that it displaces. To this saving of cost on fuel account, by the use of the later type of engine, is to be added the gain in wages and sustenance of the labour required to handle that coal.

At sea, rise of steam-pressure was for a considerable time retarded by the serious difficulty encountered in the tendency of the sulphate of lime to deposit from the sea-water in the boiler. When steam-pressure had risen to twenty-five pounds per square inch, it was found that no amount of "blowing out" would prevent the deposition of seriously large quantities of this salt. The introduction of surface-condensation was attempted as the remedy for this evil, but it was long doubtful whether its disadvantages were not greater than its advantages. It was found difficult to keep the condensers tight; and boilers were injured by corrosion, evidently due to the presence of the surface-condenser. The simple expedient of permitting a thin scale to form in the boiler was, after a time, hit upon as a means of overcoming this difficulty. Once introduced, the surface-condenser removed the obstacle to further elevation of steam-pressure, and the

rise from twenty to sixty pounds pressure, and more, soon occurred. John Elder and his competitors on the Clyde were the first to take advantage of the fact when these higher pressures became practicable.

Extreme lightness in modern machinery has been largely the result of skilful designing, of intelligent construction, and of care in the selection of material. To-day, the engines of heavy iron-clads are models of good proportions, excellence in materials, and of workmanship. The weight per indicated horse-power has been reduced from 400 or 500 pounds to a fraction of that amount. This has been accomplished by forcing the boilers, by higher steam-pressure, higher piston-speed, reduction of friction of parts, reduction of capacity for coal-stowage, and careful proportioning. The reduction of coal-capacity is compensated by increase of economy secured by high pressure, by increased expansion, elevation of piston-speed, and the introduction of the compound engine with surface-condensation.

A good marine steam-engine of the form considered standard about 1860, having low-pressure boilers carrying steam at 20 or 25 pounds pressure, expanding twice or three times, and with a jet-condenser, would require about 30 or 35 pounds of feed-water per horse-power per hour; substituting surface-condensation brought down the weight of steam used to from 25 to 30 pounds. Increasing steam-pressure to 60 pounds, expanding from five to eight times, and combining the special advantages of the superheater

and the compound engine with surface-condensation reduced the consumption of steam to 20, and with 100 to 150 pounds pressure in the "triple-expansion" engine, in some cases to 15 pounds of steam per horse-power per hour.

The next engraving illustrates the modern compound engine. Here, the cranks *Y Z* are coupled at an angle of ninety degrees, only two cylinders, *A B*, being used; and an awkward distribution of pressure is avoided by having a considerable volume of steam-pipe, or by a steam-reservoir, *O P*, between the two cylinders. The valves, *y y*, are set like those of an ordinary engine, the peculiarity being that the steam exhausted by the one cylinder, *A*, is used again in the second and larger one, *B*. In this combination, the expansion is generally carried to about six times, the pressure of steam in the boiler being usually between sixty and seventy-five pounds per square inch.

The latest form of marine engine is the "quadruple-expansion" engine, in which the steam, taken from boilers carrying a pressure of one hundred and fifty to two hundred pounds per square inch, is worked through a series of steam-cylinders, expanding continually to lower pressures as it goes, until it is finally discharged into the condenser at a pressure far below that of the atmosphere, all its energy converted, so far as the laws of nature allow, into working power. Thus expanding the steam to sixteen or twenty times its original volume, each of the four elements of the engine doing its share of the work, this machine is found capable of vastly more effective use of steam

than the older types of engine, in which the wastes within the cylinders were increased with increasing expansion in far higher proportion than the gain by expansion itself. In the various compound engines, the wastes of one steam-cylinder are utilized more or less completely in the next, thus making the total waste approximately, for the series, only that of one of its cylinders. Otherwise stated, the physical wastes of heat and steam in the "multiple-cylinder" engine of extreme expansion is approximately that only of a single cylinder, with a fraction of that degree of expansion. This is, in simple terms, the secret of the gain by the use of the compound engine. This change of type has been slowly going on, both on land and sea, ever since the time of Watt, whose contemporary and rival, Hornblower, first endeavoured to introduce the now standard system. It has now so far progressed that the marine engine demands only from one and a quarter to one and a half pounds of fuel of good quality per horse-power and per hour. In special instances, on land, where the conditions of operation could be made exceptionally favourable, the economy of the engine is claimed to have been made even greater. Even the locomotive engine is now in process of conversion into a compound engine, with good results in many cases.

As the compound engine revolutionized the methods and results of the work of the engineer in steam-navigation, so the entrance of the modern iron-clad upon the scene, about the middle of the century, revolutionized many of the methods and the results

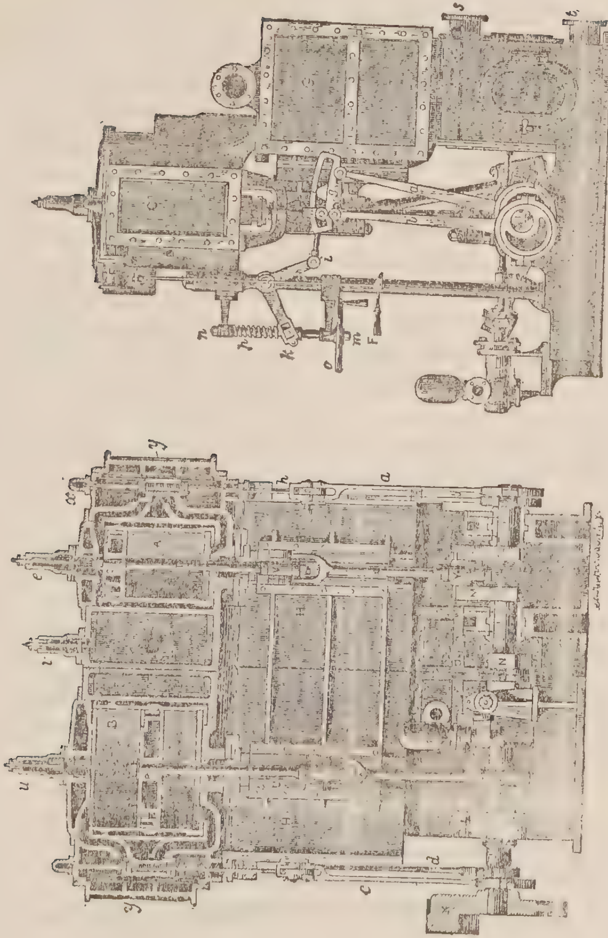

Fig. 22. —The Modern Compound Marine Steam-Engine.

of naval contests. The idea was by no means new; but like all great inventions, time had been required for it to become matured, and especially for the world to make ready for it. The Stevens Battery was probably the first real armoured war-vessel proposed and planned, and actually placed on the stocks; but the first use of the iron-clad of which we have authentic knowledge was during the Crimean War, when the French and English fleet was reinforced by a few iron-clad craft, small and rude, crude in design and thin of plating, but which were sufficient to indicate the probability that such vessels might find place in modern fleets. To-day all fighting ships are plated, and their dimensions have increased, and the thickness of their armour has been made correspondingly greater, until they are now the largest of ships, and their plating withstands the shock of guns throwing shot weighing many hundred pounds, with a velocity of nearly a half-mile in a second; but they are nevertheless still vulnerable when attacked by Fulton's method of submarine warfare with torpedoes.

Modern fleets include, in some countries, part of the more efficient and the larger merchant-vessels; and in Great Britain all the largest and fastest trans-oceanic ships are retained, under the laws of the naval code, for use by the Government in time of war, thus making an enormous and important addition to the unarmoured fleet. Lloyd's Register of Shipping of the "War-ships of the World," for 1890, gives statistical and other information regarding all navies, which will be interesting in this connection: —

	Britain.	United States.	France.	Germany.	Italy.	Russia.
Number of first-class armour-clads (18-in. armour and above)	19	. .	13	. .	10	7
Other sea-going armour-clads	41	. .	27	16	11	17
Cruisers and sloops (above 900 tons)	166	47	63	35	22	32
Gun vessels (over 600 tons)	47	3	11	4	17	4
Gunboats (over 200 tons) .	81	2	37	10	22	14
War-vessels over 14 knots .	169	19	75	44	55	23
Merchant ships to each cruiser or sloop	39	9	8	21	10	7
Merchant tonnage to each cruiser or sloop	49,000	11,000	13,000	26,500	13,600	5,000
Merchant ships to each war-vessel	38	22	7	17	4	8

The speeds of the several classes of war-vessels are as follows:—

	Britain.	France.	Germany.	Italy.	Total, including other Nations.
Over 20 knots:					
Number	50	5	2	17	94
Tons displacement	135,900	24,280	640	12,390	238,663
Number of guns .	290	48	. . .	16	350
Over 19 knots:					
Number	24	10	9	3	61
Tons displacement	96,510	30,030	10,870	7,900	208,210
"	196	58	10	26	375
Over 18 knots:					
Number	9	11	8	9	61
Tons displacement	46,660	4,980	57,2[illegible]0	71,310	2[illegible],800
"	107	5	56	72	334

The largest vessels included in the British 20-knot list are the "Blake" and "Blenheim," of 9,000 tons, and 22 knots speed, with 9¼-inch guns. France's

largest are the "Dupuy de Lôme" and "Amiral Jaures," of 6,300 tons and 20 knots speed. Germany has two small torpedo-catchers of 22 knots, and Italy several of 21 knots, while Austria has three of 23 knots speed. Spain has the "Reina Regenté," of 21 knots speed, and two sister ships. It seems that sixteen merchant-vessels are able to steam over 19 knots, several of them at 21 knots. Of this number nine are Atlantic vessels, three Hamburg-American liners, two White Star, two Inman, and two Cunard liners, while the remainder are paddle-steamers on the Channel, — eight between England and the Continent, and two to the Isle of Man. Several steamers have since been added to the list.

Among the most famous of the great steamers of recent years, — the "ocean greyhounds," as they have been well named, — are the Cunard steamers "Umbria" and "Etruria;" the still faster vessels of the Inman line, — the "City of New York" and the "City of Paris;" and the later ships of the White Star line, — the "Majestic" and the "Teutonic." They are all ships of 8,000 to 10,000 tons burden, and of from 15,000 to 20,000 horse-power. The "City of Paris," for example, cost to build over £350,000, or about $1,750,000. Her length is 580 feet, and breadth of beam 63 feet, while her two complete sets of engines are of the triple expansion type, and of about 20,000 horse-power. A manufacturing establishment requiring engines of 1,000 horse-power is considered a great enterprise, but this steamer's engines are nearly twenty times as great. The con-

Fig. 23. — The "Teutonic."

sumption of fuel averages about 350 tons a day. She has a crew of 370 men, and accommodations for 1,450 passengers. One thousand electric lamps are required to furnish light. This wonderful vessel has crossed the Atlantic repeatedly in less than six days, and perhaps with the exception of the "Teutonic" has held a first place among the fastest steamers on the ocean up to the present time (1891).

The sister ships "Teutonic" and "Majestic" are of about 16,000 tons displacement,—that is, their weight at sea is that amount,—and are the fastest ships in a fleet of about 85,000 tons total belonging to one company. The "Teutonic" has made the trip from Queenstown to New York in five days, nineteen hours, and five minutes, at a speed averaging 20.2 knots, or about 23.25 miles an hour,—a speed only rivalled by the sister ship and by the "City of Paris," which made its fastest trip in five days, nineteen hours, and nineteen minutes. These ships are of 10,000 tons burden, registered, and their engines are of 17,000 horse-power. They are 582 feet long, 57½ feet wide, and 39⅓ feet deep, of finest steel for ship construction, and can carry over 1,300 passengers, 3,000 tons of fuel, and 4,000 tons of cargo. There are twenty-five engineers, sixty firemen, and forty-eight coal-passers or trimmers, with supernumeraries, etc., which bring up the total engineer's roll to one hundred and sixty-eight persons. The crew consists of about forty men. There are twenty-five cooks and sixty "stewards." A full passenger-list gives a total of about sixteen hundred persons on board when at sea.

The engines of these great ships are of the triple-expansion variety, two independent sets being employed to drive twin screws. Their condensers contain twenty miles of brass tubes. The fires are forced by blowing-fans, which in the aggregate —

Fig. 24. — The "Henry Grace De Dieu," and the "Great Eastern."

fourteen in number — are capable of supplying about 225,000 cubic feet of air per *minute*. One hundred and twenty tons of water are converted into steam each hour, and at a pressure of one hundred and eighty pounds per square inch.

This would be sufficient for the supply of a city of over twenty-five thousand people, allowing twenty-five gallons per day to each. About 320 tons of fuel are required to convert the water into steam, each day, and the air needed for its combustion weighs about 275 tons. In the condensation of the steam about 4,000 tons of sea-water are passed through the condensers every hour, — the equivalent of the water-supply to a city of three-quarters of a million people.

The outlook, in the direction of higher speeds and better accommodation in river and ocean navigation, judged by the knowledge which we now possess and from the standpoint of the engineer, may be said to be, practically, to-day, what it has been for many years, — a gradual and steady, though probably now comparatively slow, progress in both directions. The gradual increase of size of vessel, of power of machinery, and the improvement in form of the ship's lines, may be expected to go on, more and more slowly as we approximate more and more toward a limit set by Nature to further extension and to that continually met with in the financial problem involved. As the costs of such growth increase in a high ratio, it is always the fact that it will not pay, at any given moment, to very greatly increase speeds or improve accommodations; but the state of the art of steam-navigation now reached is such that it is not likely that many will be found to mourn the fact that we advance no more rapidly. As the writer has elsewhere remarked:[1] —

1 The Forum, 1888, — "Form and Speed of Ships."

"The primary conditions are very readily determined and specified; but the working out of these conditions to a satisfactory result involves the application of principles which are the fruit of some of the most abstruse mathematical investigations, of the most ingenious and elaborate systems of experiment, and of the most extended and varied experience. In certain directions we are to-day probably very near the limit of perfect construction; but the conditions controlling the problem are so different where different ends are sought, and these differences lead to such apparently opposite lines of improvement, and to such varied forms of vessel, that it has been, and still is, to a certain extent, very difficult to reach correct formulas of application; and probably few naval architects have been able to acquire very distinct views of the best principles of design for specified purposes."

The obvious conditions of maximum speed, irrespective of other desiderata, as comfort, handiness, ease in a seaway, stability (all which must be considered to a greater or less extent by the naval architect in designing a vessel), are —

(1) Maximum power in a given weight and space.

(2) Minimum weight and volume of vessel.

(3) Minimum frictional and other resistance of wetted surfaces.

(4) Maximum perfection of form, having reference to the resistances to forward motion, and to lateral drift.

In the steam vessel "stiffness" is unimportant; and stability becomes essential only as affecting the motion

of the ship in a seaway, and in giving safety against excessive rolling, or against overturn.

To state these principles more in detail: maximum power is obtained by designing light, powerful, and efficient engines and boilers, and by applying their energy to the instrument of propulsion in such manner as to lose the least possible proportion in friction and wasteful agitation of the water. The machinery must be as light as is consistent with strength and safety, and must be driven at as high speed, and under as high pressure as is practicable; while economy in the use of steam and fuel is a hardly less important condition of excellence. Minimum weight and volume of vessel are secured in the case of the steamer, by reduction to a minimum of weights carried, and by the surrender of the space which is ordinarily claimed for comforts and conveniences. In both forms of vessel the material used in construction determines, to a great extent, what can be accomplished in this direction. The increased use of iron and steel is bringing in much lighter hulls than could possibly have been made in wood, and has given a degree of strength and safety which the wooden hull never possessed, and never could attain. The results of study of the forms of fishes, as developed by the Great Architect of Nature, with perfect adaptation to his purposes, and the comparison of the shapes of the best ship-forms yet produced by human ingenuity and skill, seem to the author to indicate that we have attained such perfection of form and proportion that no very great or rapid advance is reasonably to be

expected in the near future, and that the problem of the fast vessel is substantially solved; while further advances in speed must be expected mainly to come of devices for increasing propelling power, of new methods of securing lightness combined with stability, and perhaps, most of all, by increasing size of ship, as we have seen the size of ocean steamers increased. The limit of speed for vessels of usual sizes, whether using sail or steam, would seem to be already very nearly reached. Every gain now made must probably be made only by the application of extraordinary care and skill, under the guidance of sound judgment and large experience.

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